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ONE HUNDRED PER CENT. OF THE GROSS RE-ceipts is the basis on which a street railway franchise was awarded in New York city by Controller Fitch on Nov. 27. This sum was bid some time ago by the People's traction Co. for a franchise for 29 miles of streets in the upper part of the city. A competing company at the time bid 6.975% of the gross receipts, but the People's Co. urged that such a bid was farcical. The matter has been in the courts since October, 1895. The routes involved form connecting links between that portion of the city south of the Harlem River and outlying territory both within and without the city.

AN ELABORATE SYSTEM OF SUBURBAN ELECTRIC lines in Cook county, Ill., is projected by the Metropolitan Traction Co., incorporated in Illinois, in 1895, with a capitalization of $6,000,000. When first incorporated the company introduced an ordinance into the Chicago City Council petitioning power to build underground and surface or elevated electric railways within the central part of the city, but the ordinance was never pushed and finally died of inanition. It is now alleged that the charter has been purchased by a number of responsible Chicago business men, who have remodeled the scheme and are prepared to push work as soon as the proper authority is granted. The present franchise asks permission of the Cook County Commissioners to construct electric trolley lines on practically all of the unocupied highways under the jurisdiction of that body, nearly 100 miles in all, and connecting Chicago with the suburban towns of Evanston, Wheeling, Elgin, La Grange, Blue Island, Harvey, Thornton, Chicago Heights, Hammond and others. The terms of the franchise are entirely inadequate to protect the rights of the public in the matter of fares, damages, guarantees of construction, compensation, and in other respects, and public sentiment in Chicago particularly is against its passage. The County Commissioners are divided in their attitude toward the ordinance, however, and it is entirely possible that it will be granted with certain modifications. The ordinance as it now stands is an entirely vicious one in its neglect of the interests of the public, but the scheme, if properly regulated, has considerable merit in its favor.

THE ELECTRIC MOTOR CARS ON THE BROOKLYN Bridge have been successfully applied to the switching of trains at the terminals and pushing them out to the point where the cable is taken; and they are now in regular service taking the place of the old steam locomotives. The chief advantage of the new system is that while one train is loading the next train can be backed down near to it, ready to take its place. The result is that there is much less crowding and the platforms are clear even in the rush hours. Chief Engineer Martin expects to shortly run trains on 45 seconds headway, and promises to do even better when the double, or gauntlet tracks are ready. The new motor cars have also been tried in running trains all the way across the bridge, with success. Four cables will soon be in place across the bridge; two of these always being in service with the weight of the heavier trains proposed divided between them.

THE TUNNELING OF UNION SQUARE, New York, to avoid the two present dangerous curves on the Broadway cable road, seems to be an eminently sensible and practicable idea. The cable company is willing to build the tunnel at its own expense, and thus to substitute a practically straight line for the present curves around the square, provided the city authorities grant permission. The tunnel would be three blocks long and interfere with no streets, as the cable would readily overcome the steep gradients required.

THE CASCADE TUNNEL, on the Great Northern Railway, in Washington, is to be completed, says the St. Paul "Press." This tunnel is 2½ miles long and would reduce the elevation of the traveled line from 4,055 to 3,150 ft. above the sea. It would be 16 ft. wide and 23 ft. high, and the estimated cost is $2,000,000. At the present time the mountain is crossed by a switchback, 235 miles west of Spokane, famed for its scenic beauty. The tunnel would save 10 miles in distance and one hour in time.

THE NEW RADEBAUGH TUNNEL on the realinement of the Pennsylvania R. R., near Greensburg, Pa., was "holed through" Nov. 19, the heading meeting about 3 p. m. The tunnel is 2,100 ft. long, for a double track line, as described in our issue of Dec. 12, 1895. The work has been done by the Drake & Stratton Co., of New York, with Mr. James Day, as General Superintendent, and Mr. W. R. Michie, Engineer in Charge.

A NEW DOUBLE TRACK STEEL VIADUCT over Ridley Creek, one half a mile west of Media, Pa., on the Philadelphia, Wilmington & Baltimore R. R. was put in service November 28. It consists of six towers carrying 40-ft. girders, with intermediate girders 60 ft. long; the total length, backwall to backwall, being 641 ft., and height above water, 102 ft.. It supplants a single track Linville & Piper truss, with Howe truss approach at the east end, which was erected in 1877. Mr. H. C. Smith of Media, Pa., is the Engineer in charge of this division of the road.

THE MOST SERIOUS RAILWAY ACCIDENT of the week was the wreck of the Southern Express on the Pennsylvania R. R., near New Brunswick, N. J., on Nov. 25, resulting in the death of the engineer and fireman. The cause of the accident was the breaking in two of a freight train on the opposite down grade track: the wild section ran into the first section and two freight cars were derailed and thrown upon the other track just as the express came along at a high speed. The engine of the express rolled down the embankment and the two express cars and a mail car of the train left the track and were wrecked; the two first sleepers were also badly damaged, but the only persons injured on these cars were the express messenger and the baggage master.——Two engines were wrecked on the Lehigh Valley Ry., near Mud Run, on Nov. 24. An engine that had been flagged by a broken coal train ahead was run into by another engine coming after it. Both engines rolled down a 40-ft. embankment, but as the crews of both jumped before the collision, no one was injured.——One man was killed and 12 persons injured near Ensley City, Ala., on Nov. 20, by the failure of an old-fashioned wooden highway bridge of very crude design.

A GAS EXPLOSION AT PITTSBURG, PA., on Nov. 30, blew off a few sewer manholes and broke a number of plate glass windows.

THE PINTSCH SYSTEM OF CAR-LIGHTING has been adopted for the trains of the Manhattan Elevated R. R., after a thorough investigation of the subject and in compliance with the requirements of the New York Legislature. The contract with the Safety Car Heating & Lighting Co. was signed on Dec. 1 and the cars must be equipped by April next. Gas-works will be erected by the Pintsch Compressing Co., at 159th St. and Eighth Ave., from which the cars will be supplied.

THE NEW TWIN-SCREW STEAMER "La Grande Duchesse" for the Savannah Line (to run between New York and Savannah) left New York on its first regular trip Nov. 28. The vessel is 404 ft. long over all, 47 ft. 9 ins. beam, and 37 ft. 4 ins. deep, the hull framing being specially designed for mounting guns, as the vessel is classed as an auxiliary cruiser. The twin screws are driven by two quadruple expansion engines of 3,700 HP. each, steam being supplied by eight Babcock & Wilcox water tube boilers. The coal is brought from the bunkers by a conveyor, and the fireroom coal buckets are suspended from trolleys running on an overhead rail. The normal steam pressure is 210 lbs. There are two Sturtevant blowing engines delivering air to the firerooms, and two Westinghouse high speed engines for the electric light plant. A vertical engine drives the anchor hoist, this engine having been built by the American Ship Windlass Co., of Providence, R. I. The ship can accommodate 700 passengers, and all the first class staterooms have telephone connection with a central station. The ship and engines were built by the Newport News Shipbuilding & Engine Co., of Newport News, Va., for the Ocean Steamship Co., of New York city, which company operates the Savannah Line.

THE HAMBURG-AMERICAN STEAMSHIP "PENNsylvania," now nearly completed at Belfast, is to be the largest merchant steamship afloat. She is 560 ft. long on the water-line, 62 ft. beam, 41 ft. deep from upper deck to top of keel, draws 26 ft. of water, and is 20,000 tons dead weight with 30,000 tons displacement. The average speed is to be 14 knots, and she will accommodate 1,228 passengers.

THE LOWEST BIDS FOR STREET CLEANING, garbage collection and removal for the year 1897, received at Philadelphia on Nov. 25, aggregated $847,750, which was $65,832 more than the appropriation for the same service for the current year, and $78,750 less than the estimates. The garbage collection and disposal bids for 1897 make up $520,550 of the $847,750. The lowest bids for this service were submitted by the present contractors on the territory now covered by them, three districts being served by the American Incinerating Co., which uses the Arnold system of utilization, and two districts by the Philadelphia Incinerating Co., which employs Smith furnaces. The lowest bids for each class of work in each district are given in our Construction News Supplement.

TYPHOID FEVER AT PATERSON, N. J., is reported as far above the normal for November. The water supply is said to be the source of infection, but results of a careful investigation of the subject have not been made, or at least have not been made public. Water is taken from the Passaic River, above the Great Falls. The population above this point is small, compared with that below.

TRAFFIC ON ASPHALT PAVED STREETS in Milwaukee has recently been investigated at the instance of the Warren-Scharf Co., which requested the city authorities to take a count of the traffic on the principal streets. This covered seven days in September and the period between 6 a. m. and 7 p. m. Four of the seven days were cloudy; in two of them there was slight rain and in one a continuous rain. The greatest number of vehicles passing in any day of 13 hours was 5,146, and the smallest was 1,328, on Sunday. The daily average was 4,090.61. The greatest number of horses was 6,930, and the least 1,700; the daily average of horses being 5,433.40. Electric street cars were not counted as traffic, as they were supported by the rails; but the daily average of such cars was 1,902 for the 13 hours selected. The speed record showed that 48% of the horses were walking and 52% trotting. Of the weights moving, 38% were moving at a walk and 62% at a more rapid rate. The proportion of vehicles weighing less that one ton, with their load and outfits, was 29.7% of the whole; of heavier loads, 24.83%, and of horses 45.47%. The pavements showed the effect of three years' use. The average daily number, class and weight of horses, vehicles and loads is shown in the following summary of the schedules:

	Horses.	Vehicles.	Tons.
Loads under one ton:			
Walking	1,933	1,243	1,438
Trotting	2,719	2,304	2,512
Loads from one to three tons:			
Walking	543	281	834
Trotting	119	61	182
Loads from three to five tons:			
Walking	393	196	982
Trotting	5	3	13
Loads over five tons:			
Walking	3	1	5
Horses not attached:			
Walking	17	—	8
Speeding	1	—	½
Electric cars	—	1,902	—
Total daily average	5,433	4,091	5,974½

The average weight of daily traffic to each foot in width of roadway, not including weight of street railway cars, was 119.486 tons.

THE NEW YORK AND NEW JERSEY BRIDGE CONstruction Co. has made a contract with the Union Bridge Co., of New York, for the building of the bridge over the Hudson River, at a cost not to exceed $25,000,000, and under a bond of $1,000,000 for faithful performance of the contract. Mr. Swan, the secretary of the bridge company, says that the bonds for this work will soon be offered to the public.

RESTRICTION IN THE HEIGHT OF BUILDINGS, in New York city, is being considered by a special committee of the New York Board of Trade and Transportation, with Mr. G. Waldo Smith as Chairman. While the majority of the committee seem to favor restriction in height, there is considerable difference of opinion as to where the line should be drawn.

THE MT. NEBO RESERVOIR AND CANAL SYSTEM, UTAH.

By W. P. Hardesty, C. E.

(With inset.)

The Mt. Nebo Irrigation Co.'s reservoir and canal system is located in central Utah, in the counties of Juab and Utah. The system consists essentially of a reservoir with its dam for impounding water, a main canal line for carrying water, employing pipe and flumes as well as open canal, and a fine body of irrigable land well situated for general farming and fruit growing. This undertaking was first projected in 1892 by the Mt. Nebo Reservoir & Canal Co., and the preliminary surveys were made then, but it was not until early in 1895 that the present company was formed and construction begun.

FIG. 1.—VIEW OF MT. NEBO, SHOWING DAM SITE BETWEEN PROJECTING ROCKS IN FOREGROUND.

The Mt. Nebo reservoir is located in Juab Co., in the Mona Valley (being the northern end of Juab Valley), which lies between the Wasatch Range of mountains on the east and another but much lower range on the west. The valley is a broad basin with gentle slopes, and covering the lowest part of it is the reservoir site. The reservoir is mainly fed by Salt or Currant Creek, which runs through the valley from south to north. The culmination of the Wasatch Range here is Mt. Nebo, shown in the view, Fig. 1, from which the reservoir takes its name, whose summit is 12,000 ft. above sea level. Salt Creek heads on the east side of this mountain, a branch of it coming down from the divide between San Pete and Juab Cos., and, after flowing south and southwest through Nephi canyon to the town of Nephi, it turns north through Mona Valley. It has a drainage area of over 250 sq. miles, including Mt. Nebo and surrounding mountains.

Near the north end of Mona Valley the creek cuts through the low range on the northwest, the summit of which forms the line between Juab and Utah Cos. Above this point in Mona Valley the fall of the stream is very slight, but through the mountains in Currant Creek canyon the fall is quite heavy. This canyon extends but about three miles, opening out into the Goshen and Kimball Creek valleys, where are located the lands to be irrigated. The broad basin in Mona Valley spoken of, together with the narrow outlet through the solid rock at its lower end here, constitutes an ideal natural reservoir site. Near the head of this gorge, and where two solid rock ridges face each other, the dam is located.

Reservoir.—The Milford branch of the Union Pacific Ry. traverses the Mona Valley, and on the west side of this lies the reservoir, as shown in the map, Fig. 2. It reaches from Mona at the south end to beyond Starr Station on the north, the latter being just 75 miles from Salt Lake. With the present arrangements the reservoir covers 1,850 acres, to an average depth of over 10 ft., being five miles long by ½ to ¾ miles wide. This gives a storage capacity of 838,000,000 cu. ft., or over 19,000 acre-ft.

By enlarging the dam so as to raise the water 5 ft. higher, as is contemplated in the future, the reservoir will cover an area of over 2,400 acres, giving a storage capacity of 1,300,000,000 cu. ft., or nearly 30,000 acre-ft. In surveying the site, four complete contour lines were run around it and eight cross-section lines run across it, to obtain full information as to areas covered, capacities, etc., at different elevations of water.

Besides all the flow during the non-irrigation season of Currant Creek, whose channel runs through the reservoir, it also receives the discharge of numerous springs within and adjacent to it on the east side. It is estimated that just one year will be required to fill the reservoir.

Dam.—The dam is 210 ft. long at the top, 130 ft. at the bottom and 30 ft. high. Its base is 110 ft., and its top 8 ft. wide. A plan and profile of the structure are shown by Figs. 3 and 4. The up-stream side or back of the dam has a slope of 1½ to 1 from the crest down for 10 ft., with a slope of 2 to 1 for the remainder; the down-stream side or face has a slope of 1½ to 1, with a 3-ft. berm at 10 ft. down. The high water mark for the reservoir is 5 ft. below the top of the dam.

The body of the dam is of selected clay, hauled a few hundred feet from a borrow pit on the reservoir site. The clay was thoroughly sprinkled, harrowed and rolled in layers as built, à 5,000-lb. corrugated iron roller, shown by Fig. 5, being used. The back is faced with loose rock and heavy boulders to a thickness of 3½ ft., all laid by hand and with the interstices filled with earth by washing in with water.

The face is composed entirely of heavy gravel and loose rock, the horizontal width of the layers decreasing from 12 ft. at the foot to 4 ft. at the top, the stones being assorted and graduated in size so as to have the largest on the outside and smallest inside next to the body of the dam.

Before construction, the foundation for the dam was stripped of the surface soil, and three trenches, one at each toe and one at the middle of the dam, each about 12 ft. deep by 4 ft. wide at the bottom, were dug through the gravelly clay and into the bed rock for about 2 ft. These were refilled with the best material obtainable, sprinkled and thoroughly tamped, to shut off any possible seepage of water under the dam. Where the dam joined the solid rock ledges or abutments at the ends, these were scored or trenched to form a perfect bond between the dam and the rock faces, cement being liberally used.

At the west end of the dam is located the outlet tunnel, for draining off the water from the reservoir. This is cut through the solid rock ledge or abutment at the end of the dam, thus avoiding any risk that might be incurred in passing the water through the body of the dam itself. The tunnel is 140 ft. long, has an arched top, and is 6 ft. high by 4 ft. to 5 ft. wide, and a portion of it is located on a curve. All seams in the walls of the tunnel were well filled with cement. It was put through before the dam was built, to allow the creek to be diverted through it.

The most interesting feature of the tunnel is the gate-shaft, with the gates for regulating the flow of water. The shaft is sunk from the top of the rocky ridge directly over the tunnel, and is 4×5 ft. by 34 ft. deep. At the bottom of the shaft and closing the tunnel are the gates, two in number, of the "butterfly" type. Each gate is 2 ft. 11 ins. wide by 4 ft. high, with a clear opening of 2½ ft. wide, and is revolved by a vertical shaft 39 ft. long. The head of water sustained when the reservoir is full is 30 ft. The construction of the gates is shown by Fig. 6, while Fig. 7 is a view of the gates taken in the tunnel.

Each gate is constructed as follows: Around the 2¼-in. round cast-steel shaft a core of iron is cast, to which as a central frame are riveted the plates forming the faces of the gate. These plates are of ⅜-in. flange iron of 60,000 lbs. tensile strength. Three layers are used, one for each face and one between. The frame or casing for the gates is of cast-iron, resting on old railway rails laid horizontally and fitted to rails set vertically at the sides of the tunnel, the whole being well set in concrete.

At the top of the shaft is located the operating gear. This consists of a horizontal shaft having a worm cast on it and engaging segments of gear wheels keyed onto the ends of the vertical shafts. The horizontal shaft has a hand-wheel at each end for turning. These gates and the operating gear were made by Silver Bros., of Salt Lake City. The top of the gate-shaft is enclosed by a frame gate-house.

At the head of the tunnel is a screen for catching drift, etc., and a strong frame with slides is also in place for supporting an emergency gate, should such ever be needed.

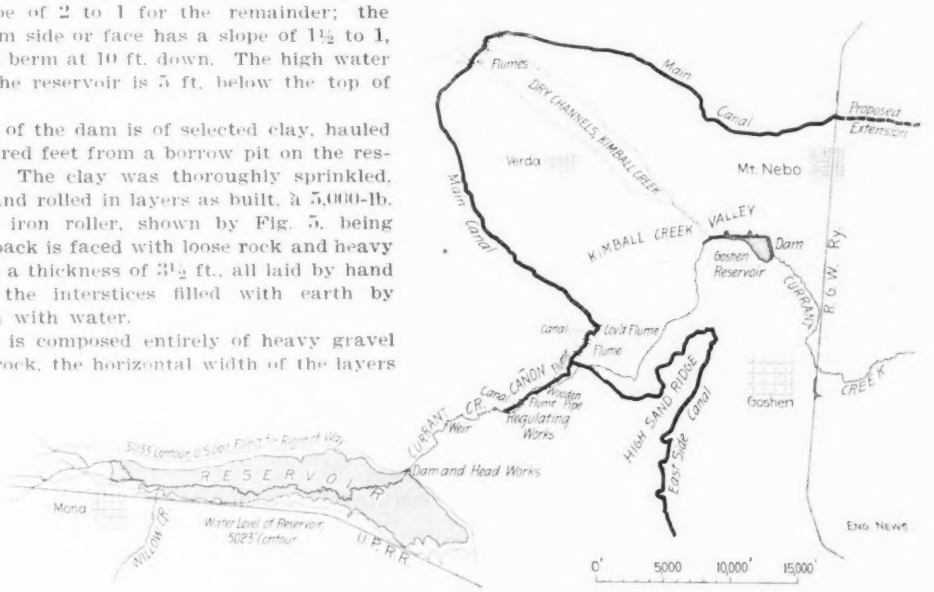


FIG. 2.—GENERAL MAP OF MT. NEBO IRRIGATION SYSTEM.

At the east end of the dam an overflow wasteway is cut through the solid rock ridge. This is 25 ft. wide and has its bottom at the flood level of the reservoir. It has ample capacity for carrying off any surplus of flood waters that may ever flow into the reservoir. The dam and all appurtenances, except the wasteway, were built by day labor, and cost about $12,000. The outlet tunnel cost $7.85 per lin. ft.

Canal System.—The water is drawn off from the reservoir during the irrigation season, being allowed to return to the creek and flow in it for about two miles before being diverted into the

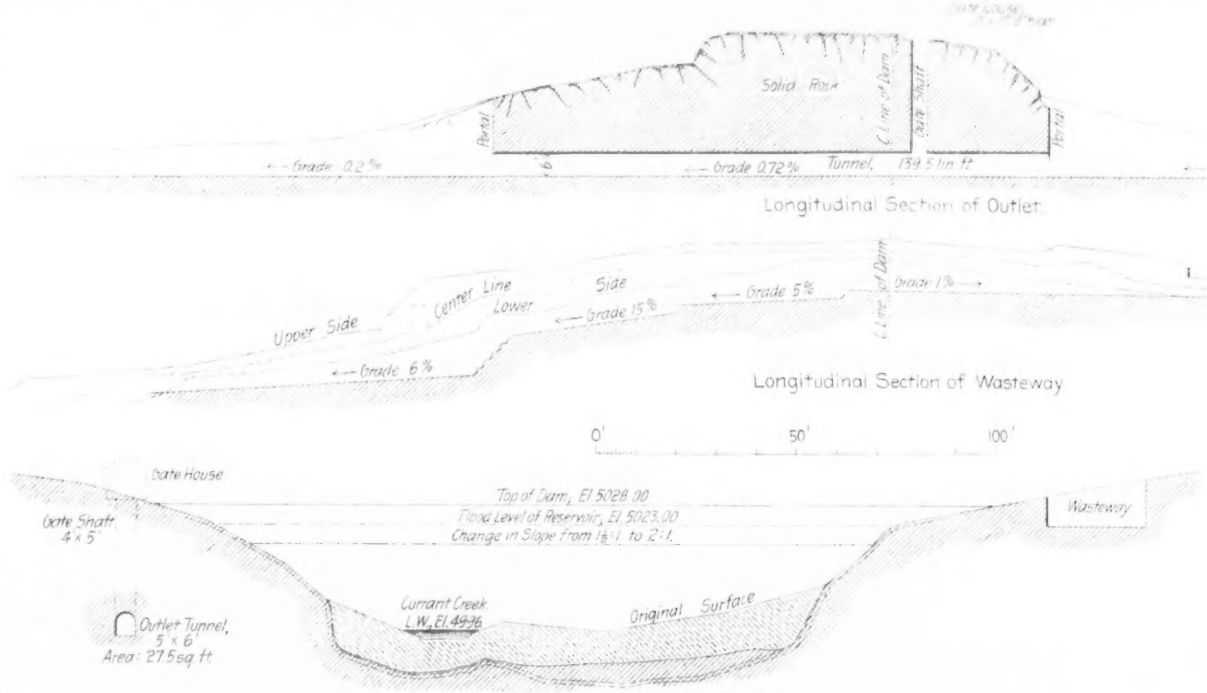


FIG. 4. ELEVATION AND LONGITUDINAL SECTIONS OF DAM, OUTLET AND WASTEWAY.

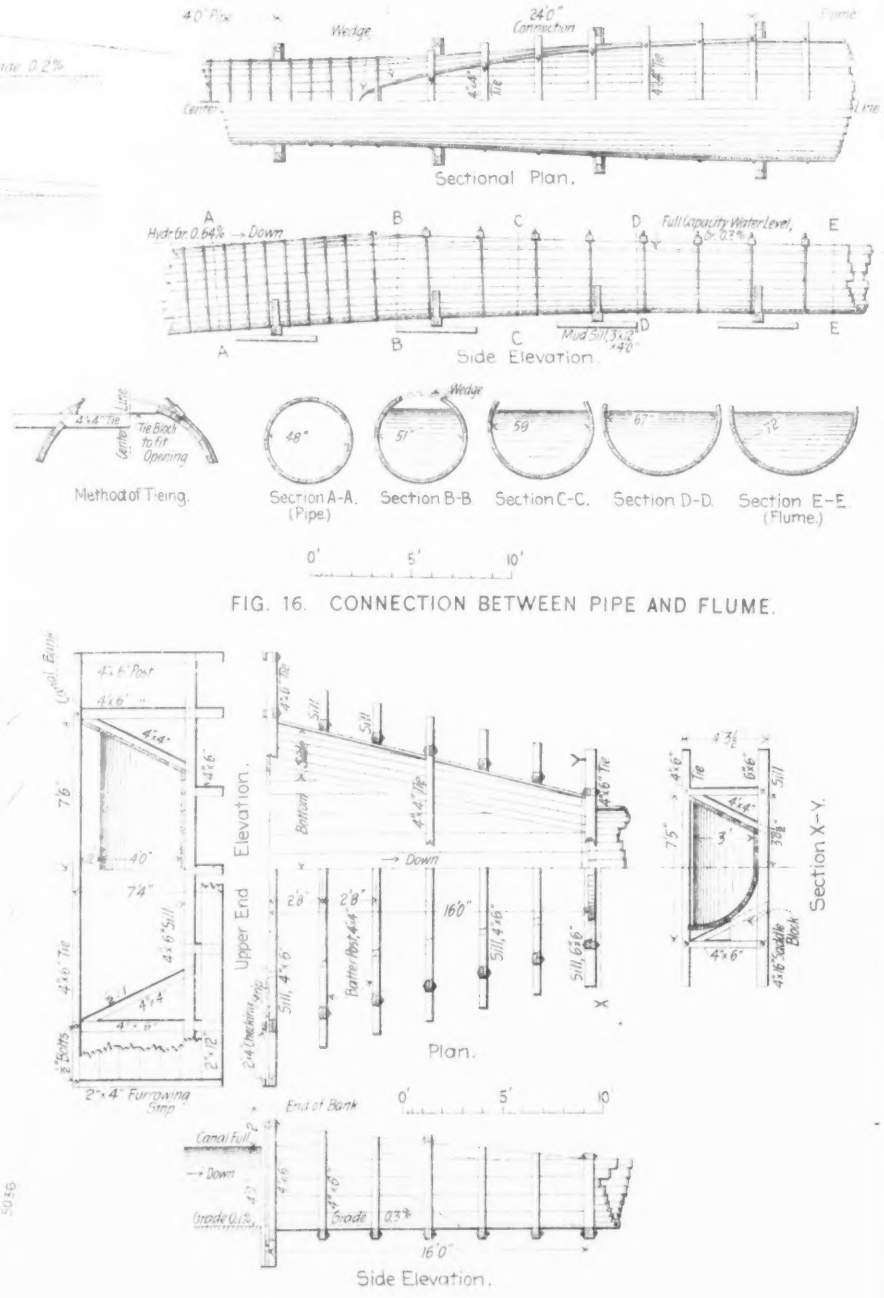
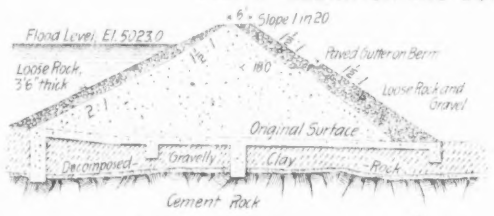


FIG. 16. CONNECTION BETWEEN PIPE AND FLUME.



Cross Section of Dam.

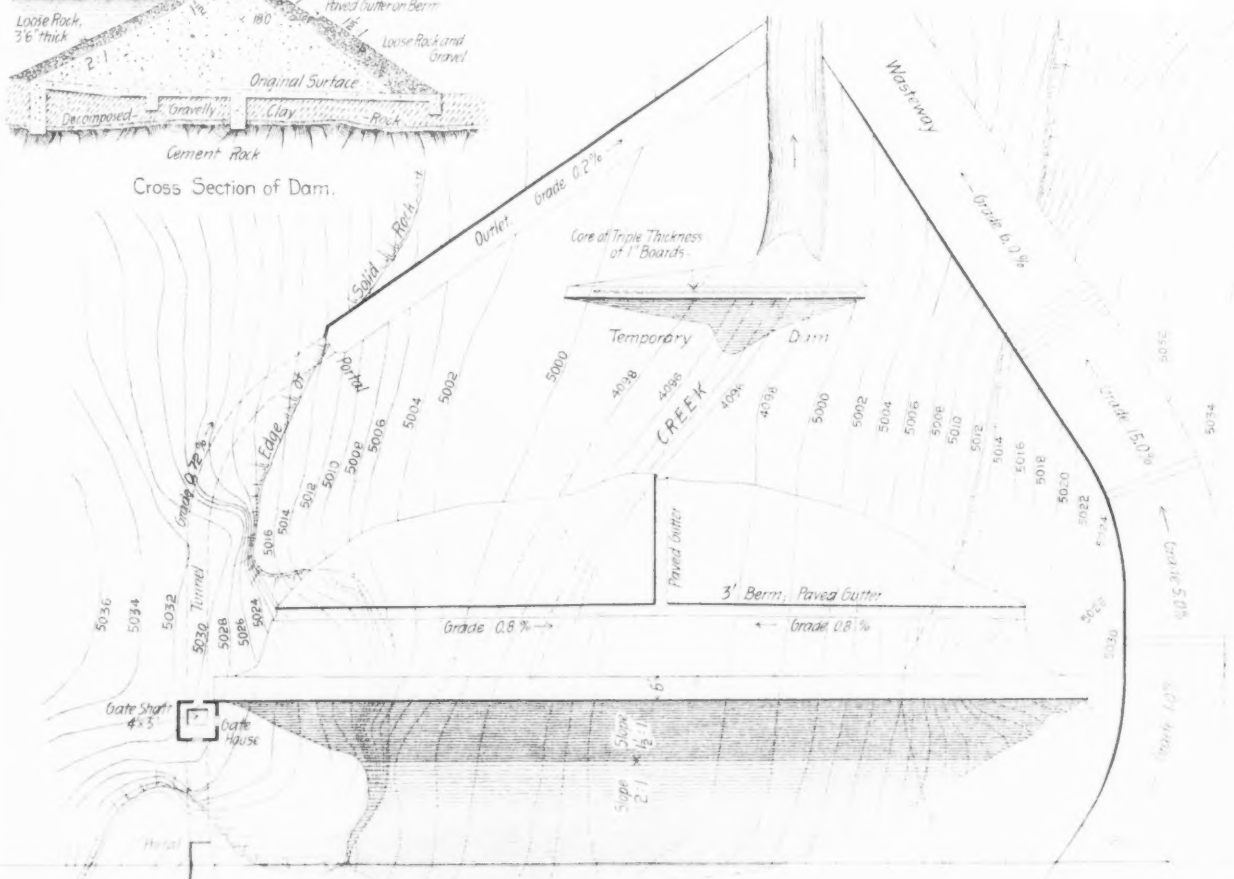


FIG. 13. JUNCTION OF FLUME AND CANAL

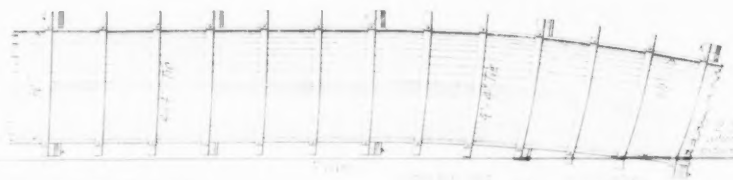


FIG. 3. PLAN AND CROSS SECTION OF DAM.

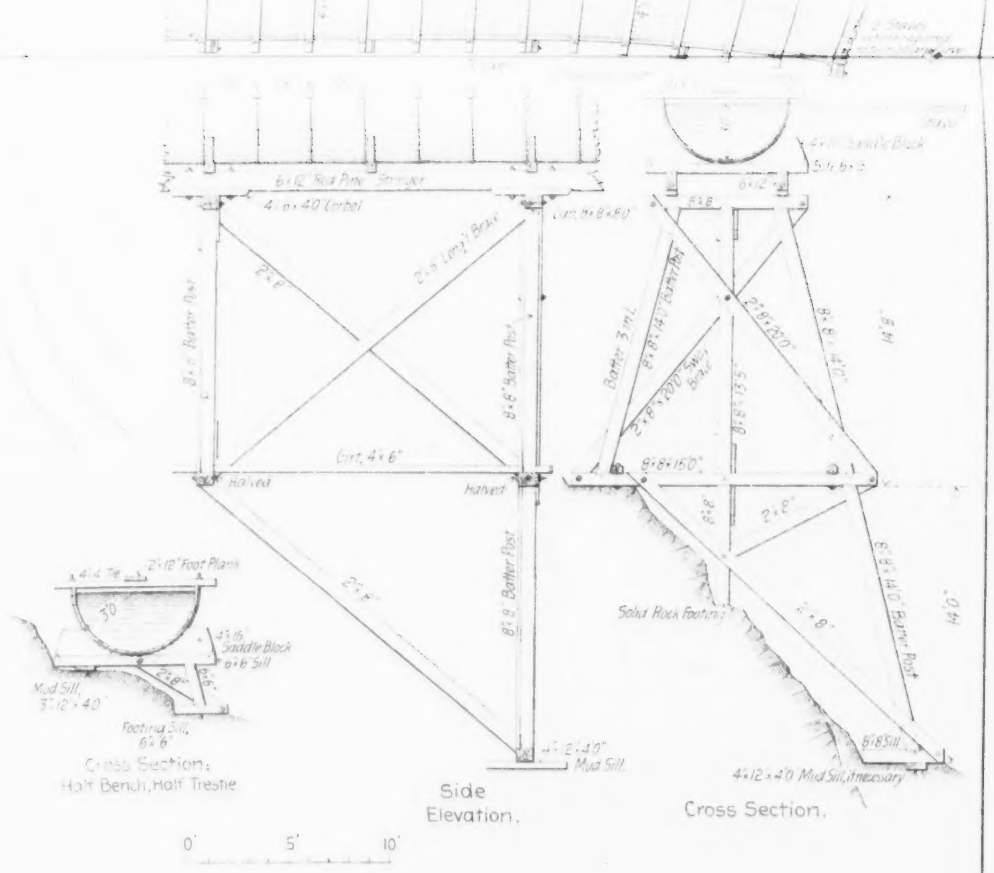


FIG. 9. STANDARD FLUME ON TRESTLE.

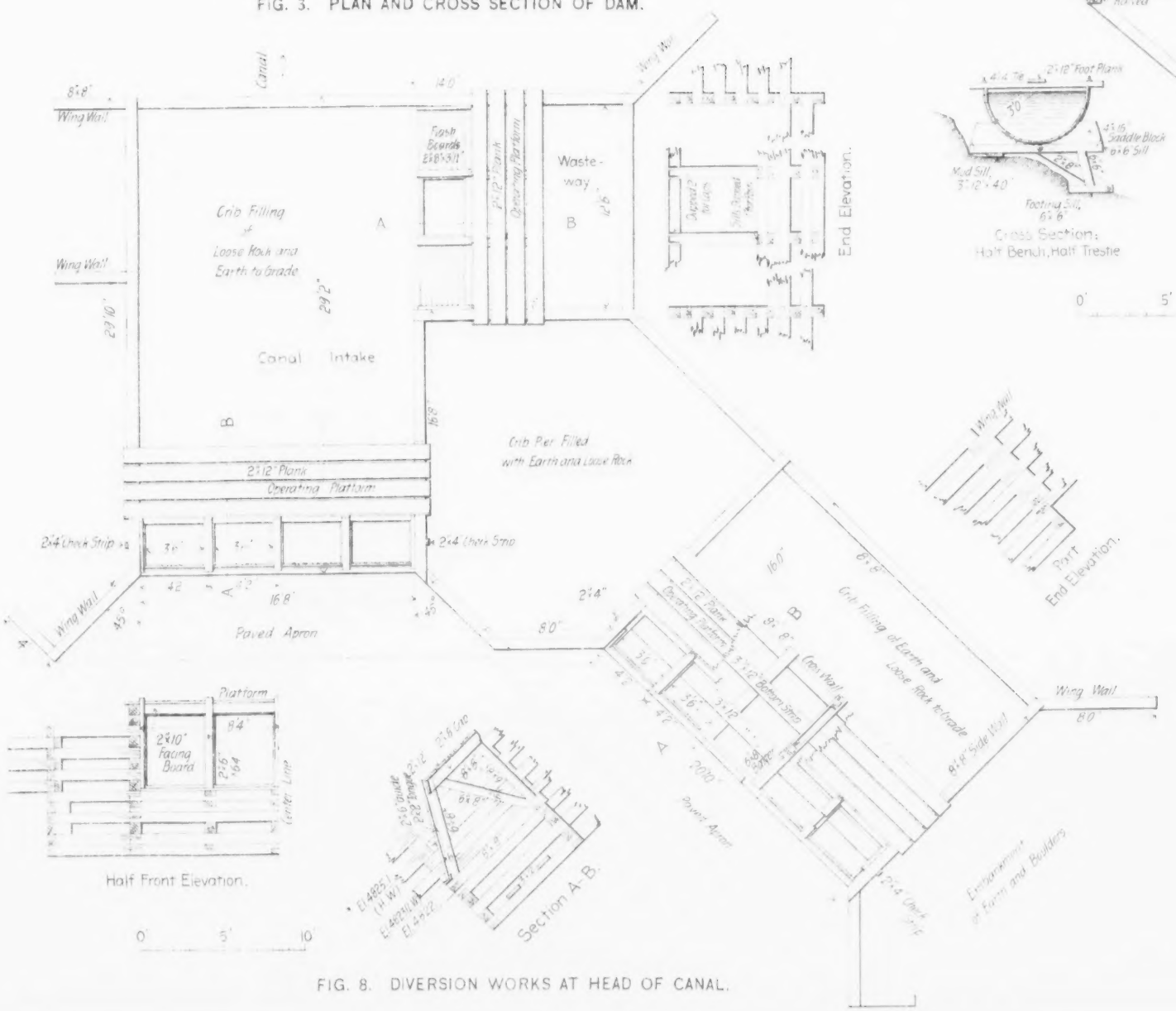


FIG. 8. DIVERSION WORKS AT HEAD OF CANAL.

THE MOUNT NEBO RESERVOIR AND CANAL SYSTEM, UTAH.

O. R. Young, Chief Engineer.

Wm. Hammond Hall, M. Am. Soc. C. E., Consulting Engineer.

CHAS. HART & SONS, LITH., 16 JESSE ST., S. F.

company's canal. In this distance there is a fall of but 31½ ft., and the diverting weir and headgates are located just above a very rapid fall in the creek's descent, amounting to 150 ft. in less than 1½ miles, thus securing all the elevation possible consistent with a short length of canal.

supporting the gates are of cribwork of 8×8-in. timbers, drift-bolted together and filled in with heavy rocks; a plank flooring is placed at the bottom, 4 ft. below grade, and heavily weighted.

The gates are on the west side of the creek. The main canal follows down the canyon or close

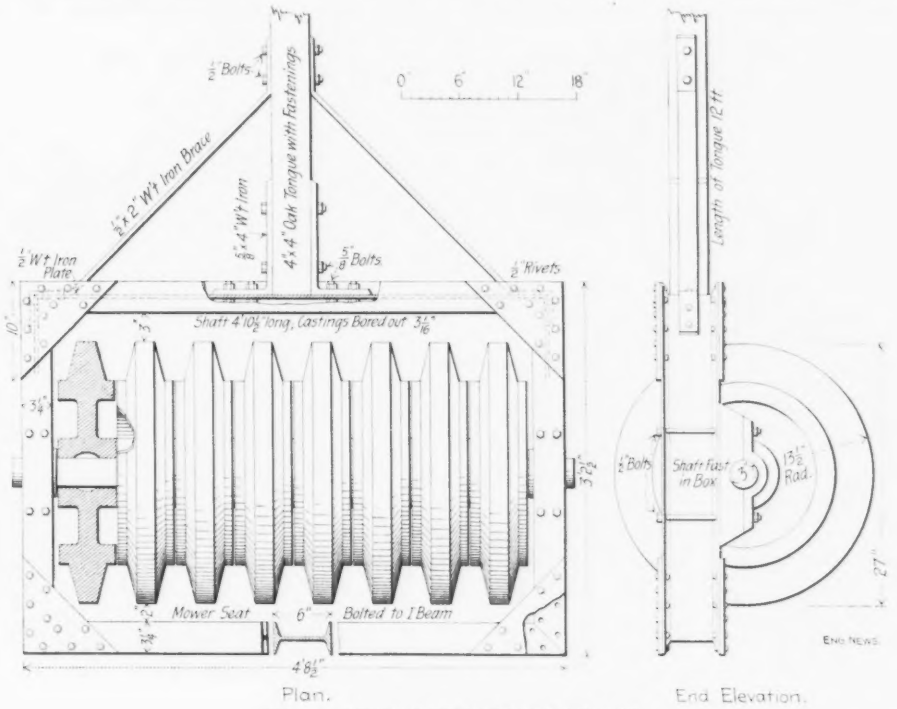


FIG. 5.—DETAILS OF GROOVED ROLLER.

The diverting weir headgate proper, and the waste weir are all of the same type, with flash boards for controlling and regulating the water. Details of these are shown by Fig. 8.

There are five bays or openings to the divert-

valley for over two miles before emerging and reaching the open valley to be irrigated. The line necessarily runs through a very rough and difficult country, requiring engineering skill of the highest order to successfully overcome all

Mr. Guy Sterling, C. E., of North Yakima, Wash. The section or shell forming the water-carrying channel is semi-circular, constructed of redwood staves, with true curved faces and radial joints, banded with ½-in steel bands, very similar to wooden stave pipe. Fig. 9 shows this flume and the standard type of trestle used to support it along the steep hill-sides. The section used for most of the flumes is U-shaped, being composed of a semi-circle of redwood 6 ft. in diameter, above which is a 6-in. fir stave on each side, with 4 ins. of it set vertically or tangent to the curved part. This gives increased depth. Fir is used because it withstands compression better than redwood in cinching up the bands.

This section allows 3 ft. depth of water, and is used where the flume has a fall of 0.3 ft. per 100 ft., giving an estimated capacity of 150 cu. ft. per sec., with velocity of nearly 11 ft. per sec. Where the fall is only 0.1 ft. per 100, a true segment of a circle is used, the shell being carried up three staves on each side above the semi-circle, the top ones in all cases being of fir. A clearance of 4 ins. above the water level is allowed. Outside the canyon, some short sections of flume have a true semi-circular shell, the diameter in all cases being 6 ft. The outer side of the flume shell was elevated, and the inner side depressed on curves, the amount being calculated by the usual formulas, the factors given being the top width of the water and the velocity. The right position was given by rolling or canting the flume in its supports it not being nailed nor fastened to these in any way. No change is made in the supports of the flume on account of the elevating.

This type of flume was first used on the Santa Ana Canal of the Bear Valley irrigation system in California by Mr. Wm. Hammond Hall, M. Am. Soc. C. E., over 2½ miles of 5½ ft. flume being built. (See Trans. Am. Soc. C. E., Feb., 1895, for very full description of the Santa Ana works.) This was built with mitered joints on curves. The Mt. Nebo flume was built the same on curves

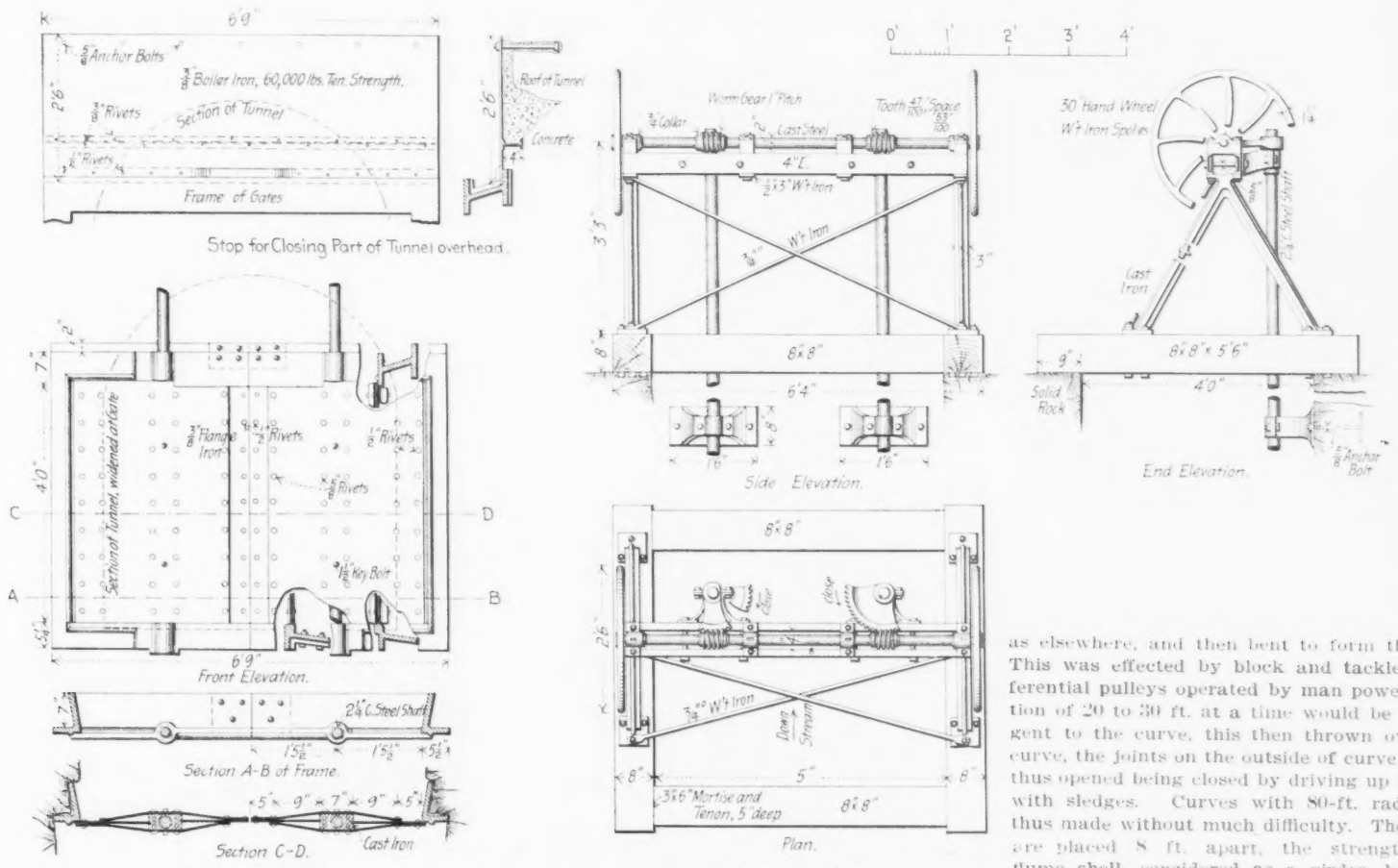


FIG. 6.—DETAILS OF OUTLET GATES AT DAM.

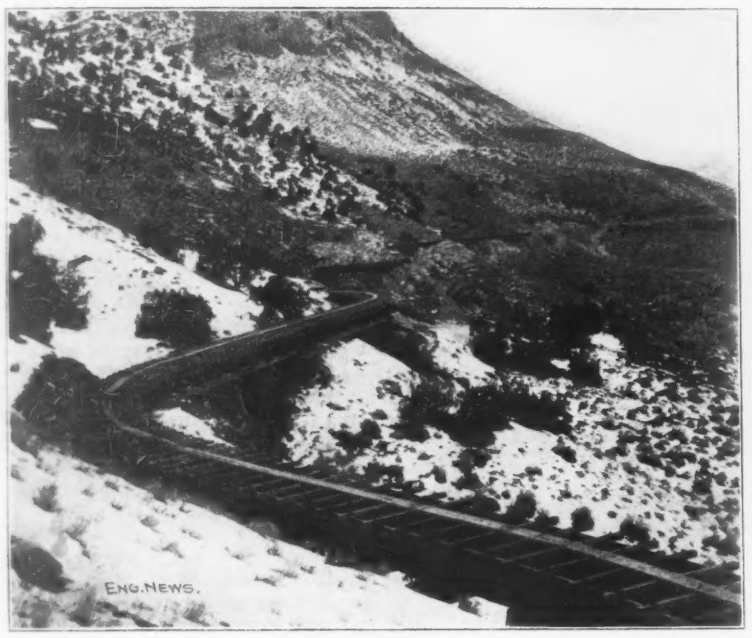
ing weir, four to the headgate and three to the waste weir, each opening being 3¼ ft. wide by 4½ ft. high. The flash boards slide in guides laid at an angle of 60° with the horizontal. The structures

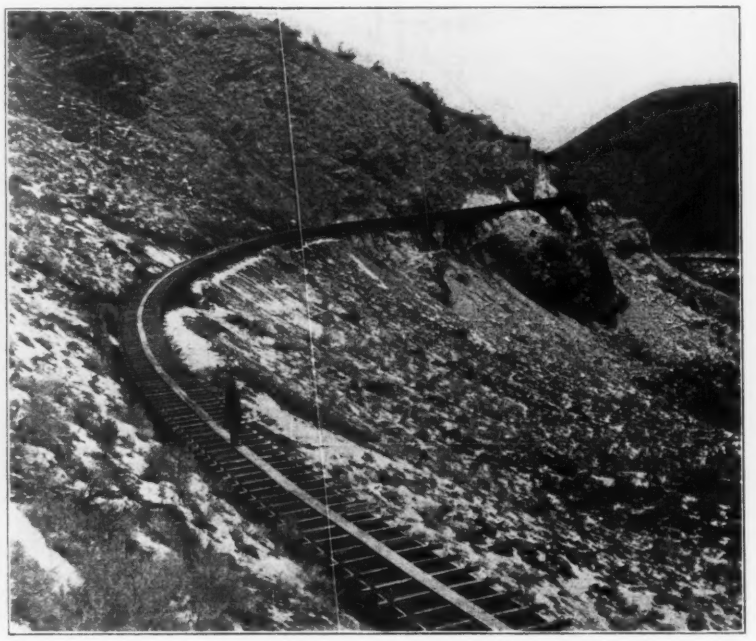
the obstacles. But about one-third of this portion could be built as open canal, the remainder being in pipe line and flumes. The fluming used is of a new and unusual type, being patented by

as elsewhere, and then bent to form the curves. This was effected by block and tackle and differential pulleys operated by man power. A section of 20 to 30 ft. at a time would be built tangent to the curve, this then thrown over to the curve, the joints on the outside of curve that were thus opened being closed by driving up the staves with sledges. Curves with 80-ft. radius were thus made without much difficulty. The supports are placed 8 ft. apart, the strength of the flume shell, considered as a girder, being quite sufficient for this span. The flume is used in all places where a canal could not be built, except one pipe line which divides it into two sections. At the head of the upper section the creek is crossed from west to east by a trestle, 400 ft. of which averages 20 to 25 ft. high. Altogether some 5,800 ft. of flume is used in the canyon.

Figs. 10 and 11 are views of the flume in the lower part of the canyon, and Fig. 12 is a view showing the junction of the flume with the canal below. The details of one of the flume and canal connections are shown by Fig. 13.

The flume is used in some places where the canal section was first built, but where the difficulty of keeping it in repair, on account of treacherous ground or of filling up, became so apparent that the flume was afterward added. The main points of superiority of this flume as compared with the ordinary rectangular or box flume are: (1) Its adjustibility to all conditions of wetness and dryness, by means of the cinching bands. (2) Its very much greater durability, there being no nail-holes nor undrained joints in which decay can set in. (3) It requires, as an average, 40 to 50% less lumber or perishable material in the flume and its framing. (4) Curves can be followed with no special construction or joints, the flume shell being built the same as on tangents.





FIGS. 10 and 11.—VIEWS OF FLUME IN LOWER PART OF CANYON.

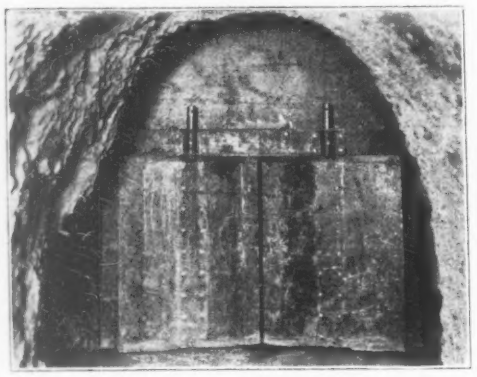


Fig. 7.—View of Outlet Gates in Tunnel at Dam.

Just before reaching the open Kimball Creek Valley a sand ridge is passed through by a cut 700 ft. long and 30 ft. deep. As sand was drifted into this by winds, the flume was run through and covered over by a double layer of 1-in. plank, as shown by Fig. 14.

There is also one pipe line in the form of an inverted siphon for crossing from the east to the west side of the canyon. This is of wooden staves, banded at intervals of 12 to 3¼ ins., according to the head or pressure of water. The pipe is 4 ft. in diameter, and has the full capacity of the canal. It is 1,967 ft. long and has a maximum head of 75 ft. at its lowest point. Here there is a 6-in. draw off or blow-off valve for emptying the pipe when necessary.

Currant Creek is crossed on a trestle with trussed stringers, the pipe being housed in for protection against freezing, as shown by Fig. 15. The rest of the pipe is covered by 2 ft. of earth.

The connections between pipe and flumes are made by gradually changing or merging one into the other, as shown by Fig. 16, instead of using penstocks at the junction, as is customary. All the pipe and the flume shell were built by the Excelsior Wooden Pipe Co., of San Francisco, of which Mr. D. C. Henny, M. Am. Soc. C. E., is engineer and manager. The contract price for the former was $3.46, and for the latter $1.54 per lin. ft. All the other lumber structures on the canal system were built by Newton & Hobbs, of Mona, Utah, native pine being used. (See Eng. News, Sept. 5, 1895, for all contract prices, under head of same).

The Main Canal is designed to irrigate the Kimball Creek Valley, reaching west and southwest from the mouth of the canyon. The East Side canal is to branch off from the other, crossing the canyon to the east side and reaching the lands in the neighborhood of Goshen on the Rio Grande Western Ry. The connection between the two canals is shown in detail by Fig. 17. This canal line drops over 100 ft., where it leaves the Main Canal, and crosses the creek by a flume.

At the connection the Main Canal has a capacity of 120 cu. ft. per sec. and the East Side canal of 30 cu. ft. The total length of the Main Canal is over 13 miles, of the East Side line, 6¾ miles.

The grades and sizes of the Main Canal vary according to the nature of country encountered and the capacity required. In the canyon the grade for canal excavation is 0.1%, for flumes 0.3%, and for pipe 0.63%. Out in the Kimball Creek Valley the grade of canal is 0.08%. The side slopes for earth excavation in the canyon work are mostly ½ to 1. For much of it a compound slope is used—that is, 1 to 1 above the water level, and ½ to 1 below that, or, in some cases, the reverse of this. Outside of the canyon the slopes are 1 to 1. All embankments are 1½ to 1. At one point a section of masonry retaining wall was put in where no bank could be used.

The following condensed table shows how the dimensions are gradually reduced, the first two portions being in the canyon, and all the dimensions being feet:

	Bank. Height.	Bank. Width.	Bottom.	Depth water.
First section	6	5	10	4
Second section	6½	5	6	4¾
Station 109 to 211	5½	5	6	4
Station 224 to 258	4	5	8	3
Station 258 to 452	3½	5	8	2¾
Station 508 to 640	3½	4	8	2¾
Station 640 to end	3¼	4	4	2½

Only one bank, that on the lower side, is used for nearly all the canyon work. Out in the open valley both banks are built. The grading was all done by Reynolds & Roylance, of Springville, Utah.

Box culverts are used for passing the minor drainage channels under the canal. Kimball Creek and its two branches are crossed by flumes like those in the canyon work, with an aggregate length of 375 ft. All the surveying and engineering fieldwork for this undertaking have been characterized by the most thorough methods, and elaborate designs and plans for all parts of the system were carefully worked out. The works and structures are all built in the most substantial manner, furnishing a good example of modern irrigation engineering.

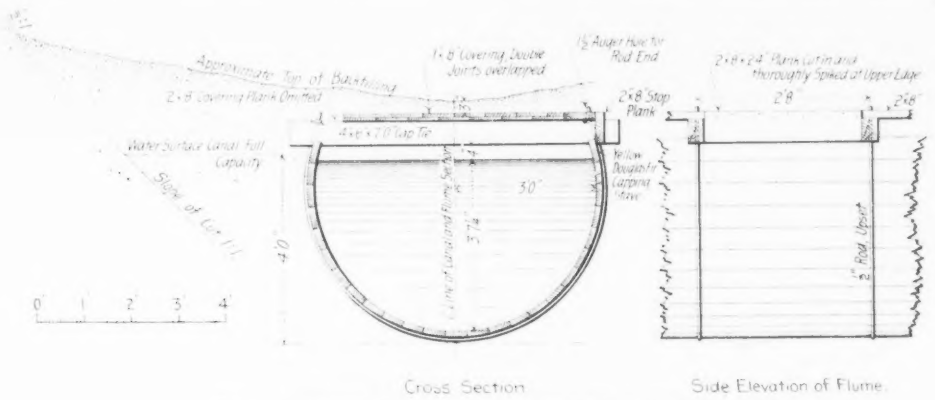


FIG. 14.—COVERED FLUME USED IN 30-FT. SAND CUT

About 15,000 acres of land can be irrigated from the system as at present designed, the amount being based on the supply of one acre-foot of water to each acre of land. The land to be irrigated is contiguous to the Tintic branch of the Rio Grande Western Ry. All this land to be watered lies in the large basin sloping to the north to

Utah Lake, and has plenty of fall, so as to insure ease of irrigation and drainage.

The original projector and organizer of the first company was Mr. H. M. McCartney, C. E. The chief engineer for the enterprise was Mr. O. R. Young, who designed and had entire charge of the construction of the whole system. Mr. Wm. Hammond Hall, M. Am. Soc. C. E., of San Francisco, was retained as consulting engineer. The president of the company is Mr. Gill S. Peyton, the secretary and treasurer Mr. E. G. Rognon. All of these gentlemen named, except Mr. Hall, reside in Salt Lake City, where are located the offices of the company.

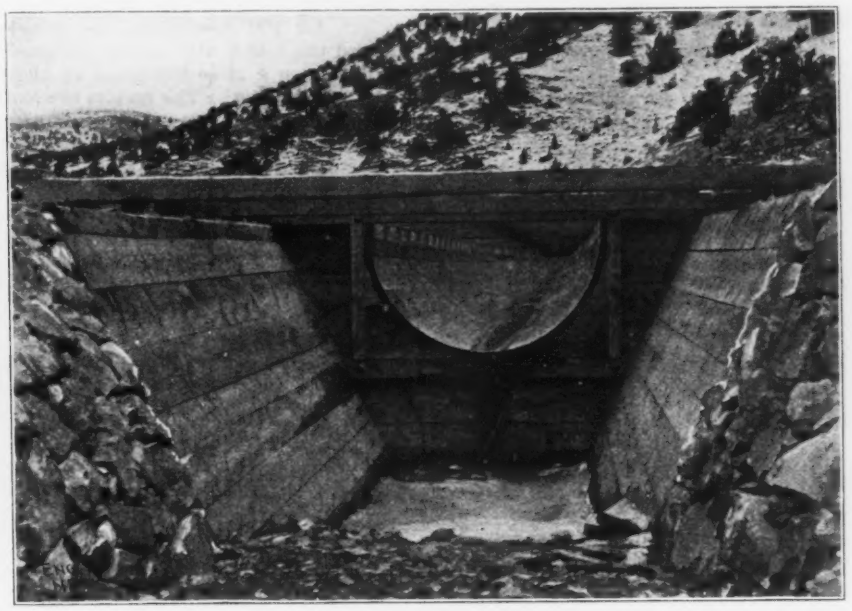


FIG. 12.—VIEW OF JUNCTION OF FLUME WITH CANAL AT LOWER END OF FLUME.

The construction work so far done has cost upwards of $100,000. The East Side canal and the laterals are yet to be constructed, but will probably be completed in the summer of 1897. The Main Canal and the two laterals so far built were operated the first season very successfully.

THE SINKING OF A WHARF AT ST. JOHN, N. B.

From the "Daily Sun" and the "Daily Telegraph," of St. John, New Brunswick, the following account is taken relating to the late collapse of a wharf on the west side of the harbor at that city: The wharf in question formed a continuation of what is known as Connoly Wharf, near the deep water terminus of the Canadian Pacific Railway. At this point a slip runs into the shore line about 1,200 ft., following the general course of what was formerly the outlet from a large tidal mill pond. Connoly Wharf occupies 400 or 500 ft. of the outer end of this slip and is a close faced cribwork structure, nearly 60 ft. high and founded 28 ft. below low water on a dredged bottom. The extreme rise and fall of the tide at St. John is about 28 to 30 ft.

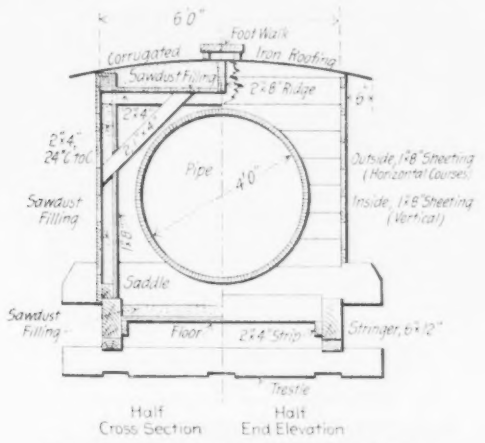


Fig. 15.- Pipe Housed In to Prevent Freezing.

The Canadian Pacific Ry. Co. practically used this terminus for the first time last winter, and in anticipation of a large increase in business the Common Council of St. John determined to increase its wharf accommodations. The Council ordered its engineer, Mr. Peters, to prepare general plans, with the expectation that the Canadian Pacific would make more detailed examination and carry out the work in accordance with an agreement which required that company to provide terminal facilities as fast as the trade would develop, in consideration of the Carleton Branch Ry. handed over by the city authorities. Mr. Peters made no cross-sections, but submitted a general plan calling for dredging and a crib structure similar to Connoly's Wharf. But the railway company, says the "Telegraph," objected to the crib plan as being too expensive, and recommended a pile wharf, and it proposed to pay a cash sum of $50,000, and to lay tracks and otherwise provide for loading and discharging steamers, but to leave the actual construction to be done by the city.

The City Council adopted the cheaper plan, with a supposed saving of $60,000 in cost, though City Engineer Peters objected to the piling system and declined to have anything to do with it. Another engineer was put in charge who attempted to make the best of the plans, though a director of works, not an engineer, was placed upon the work with almost equal authority under the specifications. The result was the slipping out of the new wharf and its total collapse. The Canadian railway engineers defend their recommended plan by claiming that a cribwork would have met the same fate, as the accident was due to a land slip. The papers mention similar slipping away of the ground at this same Sand Point on March 17, 1870.

The "Daily Sun" enters more fully into the actual construction of the pile wharf as follows: In the first place the basin for vessels had to be dredged to a depth of 28 ft. below low water. On one side of this dredged space the wharf was built by driving four rows of piling, 18 ft. apart, between centers of rows, making a wharf 24 ft. wide. Along the line of the wharf the piles were 10 ft. apart. These piles projected about 4 ft. above low water mark as driven, and they were supposed to be driven as deeply into the mud, mixed with chips and sawdust, as a heavy hammer would drive them; but how far is not stated. Upon the piles, as cut off 4 ft. above low water, a 24-ft. stick of hemlock was drift-bolted to the heads of the four piles, and upon this was built up, log-house fashion, the alternating courses forming the crib. For about 100 ft. in length of the wharf the top of the crib was 57 ft. above the bottom dredged, while the rest was not completed at the time of the accident.

About 40 ft. back of this wharf and just behind the top of the slope a shallow crib had been built to act as a retaining wall in supporting the gravel filling brought in on trains running on two lines of pile trestles. Between this crib and the wharf a large number of piles were driven, forming supports to proposed warehouses, etc., and these piles were tied to the wharf and to the back-crib with the purpose of anchoring the whole structure and especially the main crib.

At the time of the accident about 1,600 tons of gravel and sand had been unloaded on a length of 350 ft., and six gravel cars were standing upon the trestle; these cars were first noticed as canting inward along with a settling of the trestle. The cars were hauled out, but the settlement continued and the anchor piles, designed to add to the strength of the structure, transmitted the thrust of the settling trestle and

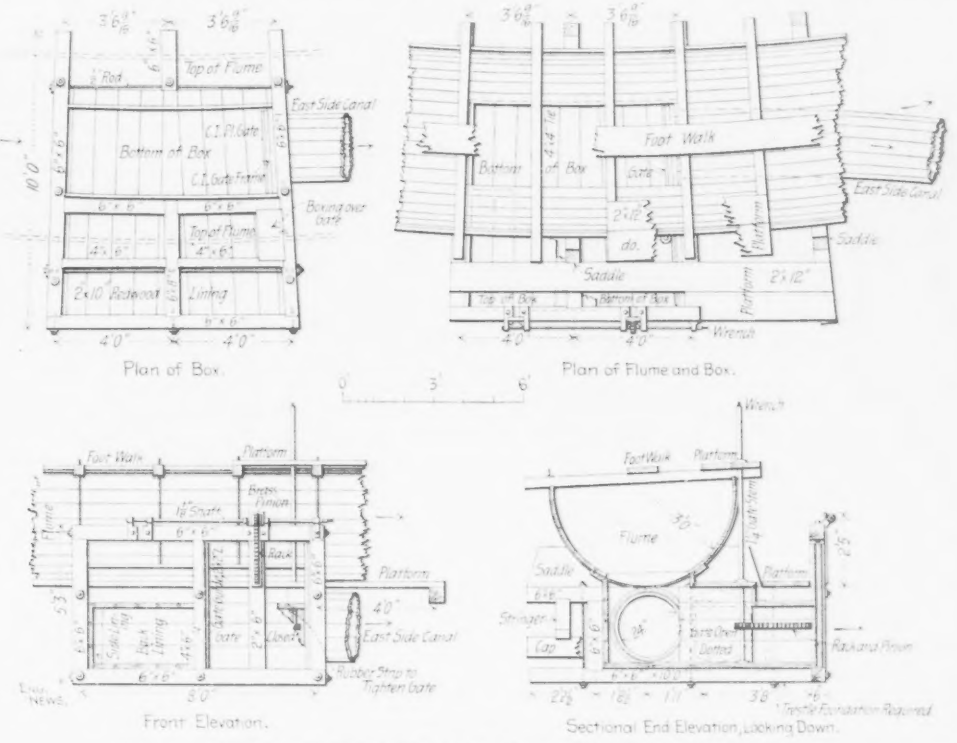


FIG. 17.—CONNECTION BETWEEN MAIN AND EAST SIDE CANAL SYSTEMS.

back-crib to the superstructure of the wharf; finally about 300 ft. of the wharf was pushed out for a distance of 5 to 8 ft., and the piling close behind the wharf sunk from 6 to 10 ft. The trestles carrying the tracks canted in towards the shore, and the anchor piles and back-crib canted out towards the wharf. Repairs will require the removal of the whole superstructure, and of most of the piles; and it is suggested that as this

would cost probably as much as the original work, it would be wiser to reconstruct with cribs, similar to the Connoly Wharf, sunk to dredged bottom without piles.

Mr. Earle, the engineer in charge of the wharf in question, recommended an entire change of plan. Mr. Earle says that piling is not practicable on this site as there is evidence of soft clay strata underlying the line of the wharf, and the pile foundations of other wharves nearby show gradual outward settlement. He now proposed to dredge to 4 ft. below the channel to a width of at least 55 ft., and to build a crib-wharf with a base of 50 ft., and return cribs 20 ft. wide, extending back about 100 ft. at intervals of 120 ft. Col. Moore, in criticising this plan, approved of cribwork, but thought that return cribs 12 to 15 ft. wide and extending back 25 or 30 ft. would be sufficient for the conditions imposed.

The "Daily Record," of St. John, of Nov. 9, gives the results of a special meeting of the harbor improvement committee, from which it appears that the dredged slope was 1 on 1½. Soundings taken after the accident show that whereas the water was originally 25 to 28 ft. deep in front of the wharf, depths of 13, 16 and 20 ft. are now found. The piling of the wharf proper and the lines of anchor piles were driven into this slope; but the question not determined by any evidence given is that of how far into this mud the piles were driven. The general evidence favors a slide of the original bottom material, carrying out with it the cribs and the piles; the slide being brought about by the back-filling disturbing the general conditions of load which this material would usually support. An almost similar case occurred in connection with the Chignecto Marine Ry., in building a wharf on the Aulac River. In this case the same extreme range of tide was encountered and the piles were firmly driven into the natural slope of the river bank. They were simply capped and floored, without any cribwork; but it was proposed to fill in behind this wharf, and when a very small portion of the filling was in place the superincumbent weight forced the mud out below and the whole structure was carried into the river. We are indebted to the courtesy of Mr. G. Simeon Armstrong, M. Am. Soc. C. E., for collecting and furnishing to us the general information upon which this account is founded. While stating that the pile wharf was the contractor's idea, and had no connection with the engineering operations of the railway company, Mr. Armstrong believes that the case was one calling for a well-ballasted crib of proper dimensions and foundation, with the filling deposited immediately behind it and carried back, to guard against any sweeping slide. Since writing the above, the whole cribwork has slipped out into the basin, and the entire work is a wreck. Great cracks appear in the ground at the top of the inshore slope. While the evidence points to a land-slide as the active cause, the case may be quoted as one where a board of aldermen knew more than the engineers and contractors, and, as is usual in such cases—"got left."

WORK OF THE HOOVER & MASON CONVEYOR ON THE CHICAGO MAIN DRAINAGE CHANNEL.

In Engineering News of June 20, 1895, the double cantilever conveyor used for excavating and conveying earth on Section H of the Chicago Main Drainage Canal was described in some detail. At that time, however, very little actual work had been done by the machine and figures of output could not be given. These figures are now available, and are given herewith. By referring to the accompanying illustration reproduced from the issue above noted, the method of operating the conveyor will be understood. The truss spans the channel and carries an endless belt to which are attached steel pans. This belt carrier follows closely the finished lines of the bottom of the channel, and lies close up against the working face. A double-ended plow operated by steam cuts successive prisms of material off the end face and the excavated material rolls into the pans. As the pans reach the extremity of the cantilever and pass over the drums, the earth with which they are filled falls out. For further details of construction and operation the article referred to above can be consulted.

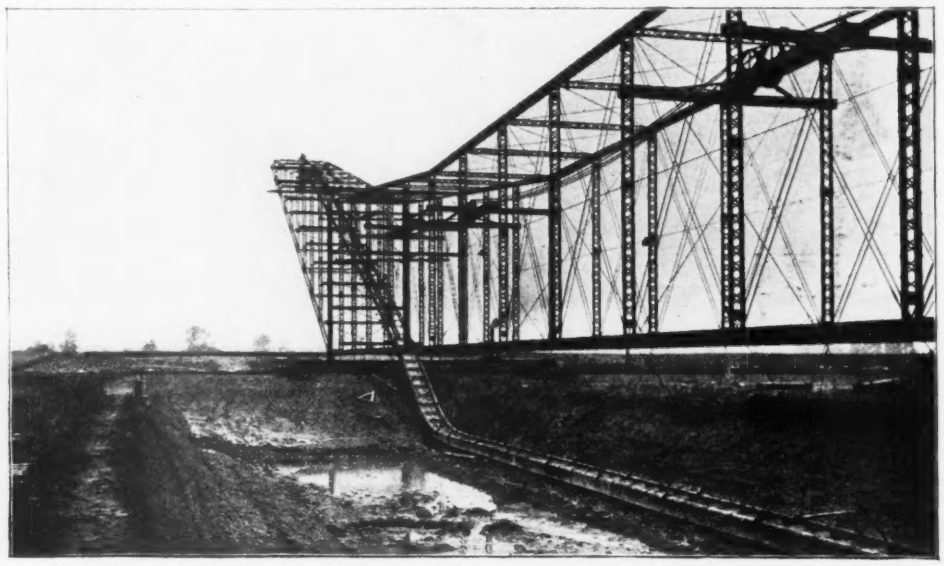
The figures of operation given us cover the three months from April 25 to July 25, and include every operation and expense to complete and trim the channel to grade. They are as follows:

Labor cost, as per pay roll	$4,714.85
Coal, 270.9 tons, at $1.70 per ton	460.54
Oil, waste, repairs, supplies and all other expenses	192.39
Total cost for three months	$5,367.78
Total cu. yds. excavated as per engineers' estimate	66,238
Total cost, per cu. yd.	8.1 cts.

This cost per cu. yd. is made up as follows:

Cost of labor	7.12 cts.
Cost of coal	0.69 "
Cost of grease, oil, waste, repairs, supplies and all other expenses	0.29 "
Total	8.10 cts.

These figures cover every detail, and moreover have been obtained while working on a face only 33 ft. high while the machine was designed for a face 36 ft. high. This reduction in height was of considerable significance on the canal work as the top 3 ft. comprised a large percentage of the total excavation and was moreover a soft prairie loam, while the material beneath was a very hard clay. As it is, however, the results are very favorable when it is remembered that the actual contract price of excavating this class of material on the Drainage Canal runs from 19 cts. to 29 cts. per cu. yd., the last being the price on Section H.



ENDLESS BELT CONVEYOR FOR EARTH EXCAVATION ON SECTION H, CHICAGO MAIN DRAINAGE CHANNEL.
Designed by Hoover & Mason, Kansas City, Mo. Gohan & Byrne, Contractors on Section H.

PROPER SPEED FOR ROPE POWER TRANSMISSION

According to a paper read recently by Mr. Abram Combe, before the British Institution of Mechanical Engineers, the speed of rope originally adopted over 30 years ago, 3,300 ft. per minute, has been found to give the best results, although speeds far exceeding this have been used in many instances. With the higher speeds it is said that the gain of power is counteracted by loss from atmospheric friction, centrifugal action, and wear on ropes and bearings. Mr. Combe gives the following sizes of ropes and diameters of pulleys, with the horse-power that may be transmitted by each size for each 100 revolutions per minute:

Diam. of rope.	Diam. of pulley.	Ratio of diams.	HP. for 100 revs. per min.
1¼ in.	3 ft.	1 to 28.8	5
1½ "	4 "	1 to 32.0	8
1¾ "	5 "	1 to 34.3	11
2 "	6 "	1 to 36.0	15

For other sizes of pulleys the power transmitted is calculated to be increased in direct proportion to the diameter of the pulleys. Mr. Combe further says:

Waen working under the most advantageous conditions —for instance, where the ropes are running horizontally at good speeds, with the pulleys at a proper distance apart, and with the bottom rope acting as a driver—the above bases may be increased by 20 to 25% with safety. On the other hand, when the ropes are working under unfavorable conditions, with centers of pulleys too close together or ropes running vertically, these bases must be diminished by 20 to 25%. The exact amount of increase or decrease on these standard bases has to be determined in each individual instance, according to the circumstances under which the ropes are working.

Desiring to compare the figures given above for horse-power transmitted by different sizes of ropes with those given by American writers on the subject, we have calculated the horse-power for a speed of 3,300 ft. per minute from the figures given for 100 revolutions per minute and compared the result with figures obtained by interpolation from a table published by the C. W. Hunt Co., of New York The results are as follows:

Diameter of rope, ins.	1¼	1½	1¾	2
HP. at 100 revs. of pulley (Combe)	5	8	11	15
" " 3,300 ft. per min. (Combe)	17.5	21.0	23.1	26.5
" " 3,300 ft. per min. (Hunt)	18.5	25.4	36.1	47.1
" " 5,000 ft. per min. (Hunt)	21.4	30.8	41.8	54.8

In Mr. Hunt's table the driving power of a rope appears to increase as the square of its diameter, as might be expected if the larger ropes were of the same quality and strength throughout as the smaller ones, but in Mr. Combe's table the driving power increases at a rate which is even less than the direct ratio of the diameters. An American designer working by Mr. Hunt's table would use a 2-in. rope at 5,000 ft. per minute to drive 54.8 HP., while an English designer following Mr. Combe's figures and his statement that the best results are obtained with a speed of only 3,300 ft. would obtain less than half the power from the same rope, or only 26.5 HP. By the latter rule more than twice as many ropes would be required for a given installation, and the consequent expense might, in American practice, at least, lead to the adoption of belts instead of ropes.

We doubt, however, if the figures given by Mr. Combe are to be accepted as a record of actual English practice, for an article by Mr. Wm. H. Booth, an English contributor to the "American Machinist," a few years ago, gave the "most usual practice" in Lancashire as follows: 1¾-in. cotton ropes at 5,000 ft. per minute equal 50 HP., and he gives a table of data from English practice from which we take the following:

Diameter of rope, ins.	1¼	1½	1¾	2
HP. per rope, at 4,800 ft. per min.	24	34	49	63

These figures are in every case larger than those given in Mr. Hunt's American table. It would appear that the smaller figures given by Mr. Combe for 1¾ and 2-in. ropes are due to extreme conservatism, and to the English habit of being slow but safe and sure, carried to too great an extent, and to an extent which, according to Mr. Booth's figures, is not followed by Lancashire manufacturers.

A 5,000-MILE PHOTOGRAPHIC INTERCHANGEABLE railway ticket has been agreed upon by the Central Passenger Association Committee. These tickets will cost $100 each, will bear a photograph of the purchaser and will not be transferable. The 1,000-mile "wide-open" ticket, now on sale, will also be used. The 5,000-mile tickets will cover roads in the Central district, between Pittsburg and St. Louis, but will not include the Pennsylvania R. R. lines.

THE ORIGIN OF THE BESSEMER PROCESS.*

By Sir Henry Bessemer, London, Eng.

(Honorary Member Am. Soc. M. E.)

It is generally well known that this invention had its origin in certain experiments commenced in January, 1855, for the purpose of improving the quality of cast-iron employed for founding heavy ordnance, by rendering the iron more tough, increasing its tensile strength, and making it less subject to injury by abrasion. I was aware that Fairbairn and others had sought to improve cast-iron by the fusion of some malleable scrap-iron along with the pig-iron in the cupola furnace; this fusion of scrap-iron, intermixed with the mass of coke, was found to convert the malleable iron into white cast-iron, which was at the same time much contaminated with sulphur, and thus, to a great extent, this method had failed in its object. In my experiments I avoided the difficulties inseparable from Fairbairn's plan, by employing a reverberatory furnace in which the pig-iron was fused, forming a bath; into this bath I put broken-up bars of blistered steel, made from Swedish or other charcoal iron, its fusion taking place without being further carburized by contact with the solid fuel, or contaminated by the absorption of sulphur. The high temperature necessary for the fusion of a large proportion of steel in the bath, was attained by constructing the fire-grate much wider than the bath, by contracting the width of the furnace considerably at the bridge, and also by continuing to taper the furnace slightly all the way from the fire-bridge to the downcast flue, which was connected with a tall chimney shaft. My English patent for this arrangement bears date Jan. 10, 1855. Many alterations and modifications of this furnace were made from time to time; it was found that the large volume of flame sweeping over the open hearth of the furnace was mixed with a considerable quantity of combustible gas, to consume which a hollow fire-bridge was employed, having numerous perforations made in the fire-clay lumps of which it was composed, and so arranged as to allow jets of hot atmospheric air to mingle with these combustible gases, which had the effect of producing an intense heat close down on the surface of the bath; it was also found that the admission of hot air all along the back of the fire-bridge produced a decarbonizing action on the bath; and hence the degree of carburation of the metal might be altered by regulating the admission of air. The flow of air through the hollow fire-bridge served also to moderate its temperature and render it more durable.

Some of the samples of metal which I produced by this process were, when annealed, of an extremely fine grain and of great strength. At this stage of my experiments I determined on casting a small model gun which in the lathe gave shavings slightly curled, and closely resembling the turnings from a steel ingot. The metal when polished also looked white and close-grained like steel. I was so well pleased with this casting that I took it over to Paris, obtained an audience with, and showed it to, the Emperor, who had, in fact, encouraged me to make an attempt to improve iron employed in founding heavy ordnance. His Majesty, who had desired me to report progress, accepted this experimental gun, remarking that some day it might have an historical interest, and it was in recognition of this circumstance that His Majesty, later on, intimated to me, through Colonel Belleville, his desire to confer on me the Grand Cross of the Legion of Honor, provided I could obtain permission to wear it, a privilege which our ambassadors twice refused. His Majesty also gave me permission to erect my furnace at the government cannon foundry at Ruelle, near Angouleme, to which place I went, with proper introductions, for the purpose of arranging all the necessary details. I also sent over from England several thousand special fire-bricks, etc., for the erection of the furnace.

But on resuming my further researches, after returning to London, an incident occurred which suddenly put a stop to the intended works at the Ruelle gun foundry, and, in fact, altered all my future plans and investigations.

The furnace, as it was then arranged, is shown in vertical section by Fig. 1, and in horizontal section on a line passing through openings in the perforated hollow fire-bridge by Fig. 2, where the narrowing of the body of the furnace is clearly shown, and the manner in which the jets of air were directed so as to produce an intense ignition of the combustible gases mingled with, and passing over, with the large volume of flame, from the over-charged fire-grate.

The small scale on which this experimental furnace was built (viz.: a capacity of three hundredweight only), was much against my obtaining the high temperature necessary to melt a large proportion of steel in the pig-iron bath. I was of course fully aware that a furnace of sufficient capacity to cast a five or a ten ton gun would produce a much higher temperature than it was possible to attain in my small furnace, and also that a forced draft, obtained by closing in the ash-pit and forcing air into it, would also still further increase the temperature. That this forced draft was in my mind at the time, is shown by the fact that I took out a patent for the manufacture of cast-steel, dated Oct. 17, 1855; that is, about two months after the casting of the model gun; in this patent I fully described the forcing of air by a fan, into the closed ash-pits of furnaces employed in the manufacture of cast-steel; and it has often since occurred to me that, with the additional resources still untried, I did not act wisely in so suddenly abandoning these open-hearth experiments, in favor of an entirely different system, suggested to my mind by the incident before referred to. But with my impulsive nature and my intense desire to follow up every new problem which presented itself, I at once threw myself unreservedly into this new study, which seemed to open a way to the rapid production of bars, rails, and plates, of malleable metal direct from the blast furnace.

Before dismissing this subject it may be interesting even at this distant period to speculate on what would have been the natural outcome of the open-hearth furnace experiments, had I not been so suddenly diverted from their further pursuit.

Such a furnace, with a forced draft and a capacity of ten tons, would undoubtedly have melted malleable iron or steel in a bath of pig-iron, and have decarburized it to the desired extent, for I had, in fact, in this small furnace already fused steel in a bath of pig-iron, on the open hearth of a reverberatory furnace, and as far back as January, 1855, I had claimed in my patent "the fusion of steel in a bath of melted pig, or cast-iron in a reverberatory furnace, as herein described."

This was about ten years prior to the first patent taken out by M. Emile Martin, and now generally known as the Siemens-Martin process. This patent was obtained in England in the name of Emile Martin only, and is dated Aug. 18, 1865, or more than ten years after my patent of January 10, 1855. M. Emile Martin, in his patent, says: "The manufacture is effected upon the principle of fusion of iron or natural steel in a bath of cast-iron, maintained at a white heat, in a reverberatory furnace such as a Siemens gas-furnace."

I desire to say that I make no claim whatever to the prior invention of the Martin-Siemens process, nor do I for one moment assume that my patent of 1855 furnished any information which either of these gentlemen availed themselves of; but I think I am justified in saying that the fusion of steel in a bath of pig-iron, on the open hearth of a reverberatory furnace, which I had patented and successfully effected, was, to use a favorite expression of Mr. Gladstone, "approaching within measurable distance" of that now well-known and successful process.

On my return from the Ruelle gun foundry, I resumed my experiments with the open-hearth furnace, when the remarkable incident I have twice referred to, occurred in this way: Some pieces of pig-iron in one side of the bath attracted my attention by remaining unmelted despite the great heat of the furnace, and I turned on a little more air through the fire-bridge, with the intention of increasing the combustion; on again opening the furnace door after an interval of half an hour, these two pieces of pig still remained unfused. I then took an iron bar, with the intention of pushing them into the bath, when I discovered that they were merely thin shells of decarburized iron, as represented at Fig. 3, thus showing that atmospheric pressure alone was capable of wholly decarburizing gray pig-iron and converting it into malleable iron without puddling or any other manipulation. It was this which gave a new direction to my thoughts, and after due consideration I became convinced that if air could be brought in contact with a sufficiently extensive surface of molten crude iron the latter would rapidly be converted into malleable iron.

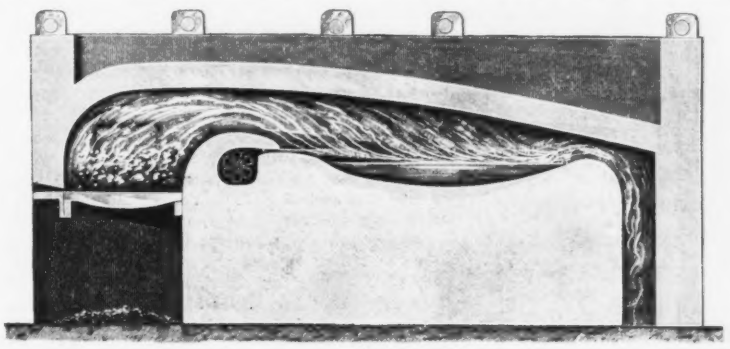


Fig. 1.

Fig. 1.—Vertical Section.

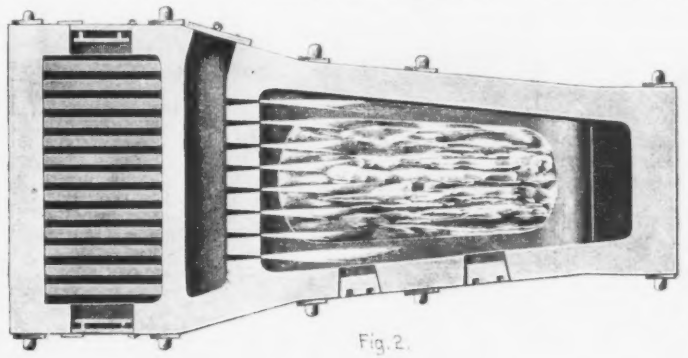


Fig. 2.

Fig. 2.—Horizontal Section.

FIG. 1 and 2.—DECARBURIZING CAST IRON IN A REVERBERATORY FURNACE.

This, like all new problems, had a special interest for me, and I became impatient to test it by more than a laboratory experiment; without loss of time I had some fire-clay crucibles made with perforated covers, and also some fire-clay blow-pipes, which I joined to a 3-ft. length of 1-in. gas-pipe, the opposite end of which was attached by a piece of rubber tubing to a fixed blast-pipe. This elastic connection permitted the easy introduction and withdrawal of the blow-pipe into and out of the crucible, as shown at Fig. 4, which represents a vertical section of an air furnace, containing a crucible, which in this case represented the "converter." About 10 lbs. of molten gray pig-iron about half filled the crucible, and 30 minutes' blowing was found to convert 10 lbs. of this gray pig-iron into soft malleable iron. Here at least one great fact was elicited, viz.: the absolute decarburization of molten crude iron without any manipulation, but not without fuel; for had not a very high temperature been kept up in the air furnace all the time this quiet blowing for 30 minutes was going on, it would have resulted in the solidification of the metal in the crucible long before complete decarburation had been effected. Hence arose the all-important question: Can sufficient internal heat be produced by the introduction of atmospheric air to retain the fluidity of the metal until it is wholly decarburized in a vessel externally heated?

This I determined to try without delay. I fitted up a larger blast cylinder in connection with a 20 HP. engine which I had daily at work, and I also erected an ordinary foundry cupola capable of melting half a ton of pig-iron. Then came the question of the best form and size for the experimental "converter." I had very few data to guide me in this, as the crucible converter was hidden from view in the furnace during the blow. I, however, found that slag was produced during the blow and escaped through the holes in the lid; this fact guided me to the construction of a very simple form of cylindrical converter, about 4 ft. in height in the interior, which was sufficiently tall and capacious, as I believed to prevent anything but a few sparks and heated gases from escaping through a central hole made in the flat top of the vessel for that purpose, as shown in vertical section at Fig. 5. The converter had six horizontal tuyeres arranged around the lower part of it; these were connected by six adjustable branch pipes, deriving their supply of air from an annular rectangular chamber extending around the converter, as shown.

Fig. 3.

Fig. 3.—Shell of Decarburized Pig Iron.

All being thus arranged, and a blast of 10 or 15 lbs. pressure turned on, about 7 cwt. of molten pig-iron was run into the hopper provided on one side of the converter for that purpose. All went on quietly for about ten minutes. Sparks, such as are commonly seen when tapping a cupola, accompanied by hot gases, ascended through the opening in the top of the converter, just as I supposed would be the case, but soon after a rapid change took place. In fact, the silicon had been quietly consumed, and the oxygen next uniting with the carbon, sent up an ever-

*A paper presented at the New York meeting (Dec., 1896) of the American Society of Mechanical Engineers. Another account by Sir Henry Bessemer of his great invention, communicated by him to the International Engineering Convention of 1890, was published in Engineering News, Oct. 18, 1890.

increasing stream of sparks and a voluminous white flame; then followed a succession of mild explosions, throwing molten slags and splashes of metal high up into the air, the apparatus becoming a miniature volcano in a state of active eruption. No one can approach the converter to turn off the blast, and some low flat zinc-covered roofs close at hand were in danger of being set on fire by the shower of redhot matter falling on them. All this was a veritable revelation to me, as I had in no way anticipated such violent results. However, in ten minutes more the eruption had ceased, the flame died down, the process was complete, and on tapping the converter into a shallow pan

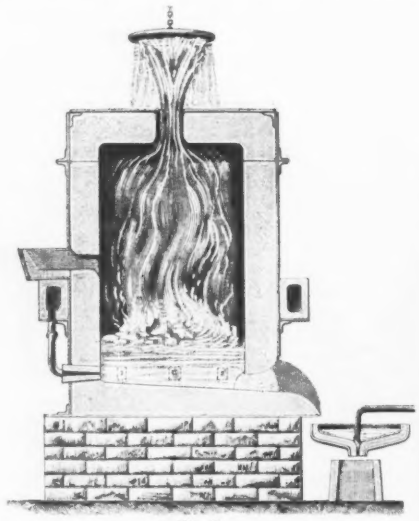


Fig. 5.

Fig. 5.—Bessemer's First Converter.

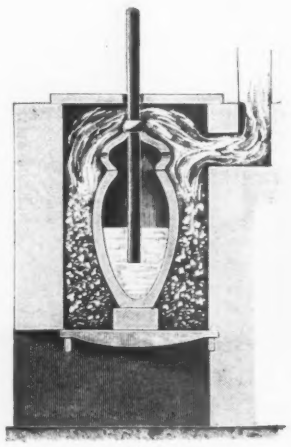


Fig. 4.

Fig. 4.—Bessemer's First Experiment—Decarburizing Iron in a Crucible.

or ladle, and forming it into an ingot, it was found to be wholly decarburized malleable iron.

Such were the conditions under which the first charge of pig-iron was converted into malleable iron in a vessel neither internally nor externally heated by fire.

I, however, desired to convert a second charge of pig-iron, which had been put into the cupola, and in order to prevent this dangerous projection upward of sparks and molten slags, a temporary expedient was resorted to which, however, failed in its object. I procured one of those circular chequered cast-iron plates so much used in the London pavements to allow coals to be put into the cellars below the pavement. This plate, which was

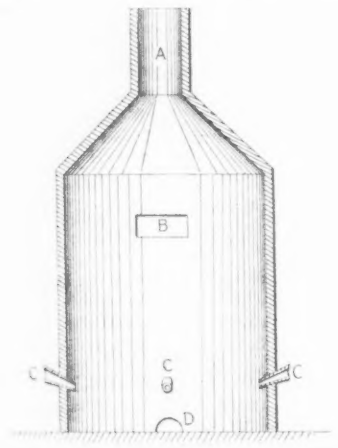


Fig. 6.—Converter Shown in Kelly's Patent.

about a foot in diameter, was suspended by a chain at a distance of 18 ins. above the central opening, in the top of the converter, as shown in Fig. 5.

This as a mere temporary device was deemed sufficient to allow the conversion of another 7 cwt. charge to be effected without any danger of setting fire to the premises. The converting operation went on quietly as before, but when the eruption commenced I saw the suspended plate get rapidly redhot, and in a few minutes more it melted and fell away, leaving the chain dangling over the opening, and allowing the slags and splashes of metal to shoot upward as before. Thus it happened that the first converter which I had constructed was at once condemned as commercially impracticable, owing to this vertical eruption of cinder, and for this reason only. All attempts to lessen the violence of the process by a reduction of the number of tuyeres, or by lessening the diameter of the tuyere pipe orifices, or by diminishing the pressure of the blast, only resulted in a reduction of the necessary temperature, and in preventing the conversion of the molten pig-iron into malleable iron. In one case the trial of a diminished area of tuyere opening, resulted in nearly the whole charge of metal, after more than an hour's blowing, being converted into a solid mass of brittle white iron similar to ordinary refiners' plate metal. Indeed, I may say that the results of all my early investigations proved to me, beyond the possibility of doubt, a fact which has since been confirmed in every Bessemer steel works throughout Europe and America, viz., that rapidity of action ending in a violent eruption are absolutely necessary conditions of success; and when we take into consideration the fact that the converted metal must be made to acquire an enormously high temperature, so that it may not be chilled in tapping, or pouring it out of the incandescent converter into a cold open ladle; that it be not chilled by the addition of a large quantity of much cooler metal employed to deoxidize it; that it does not chill and form a skull in the casting ladle during the comparatively long time required to form it into ingots; it is obvious that to carry out the Bessemer process successfully, a temperature must be obtained very considerably above the mere melting temperature of malleable iron. In order to obtain this temperature it is necessary to drive powerful streams of air into the metal, so as to divide it into innumerable fiery globules diffused throughout the whole body of metal under operation, which for the time being may be likened to a fluid sponge, with the active combustion of carbon with oxygen going on in every one of its myriads of ever-changing cavities.

It has been found that the union of carbon and oxygen takes place so rapidly at this high temperature as to produce a series of mild explosions, which are scarcely noticed in the large converters in common use which have a space for the violent expansions, of some 8 or 10 ft. in height above the normal level of the metal; in this space the violent action expends itself unseen, and is only partially recognized by a small additional quantity of slags leaping out of the mouth of the converter.

With these facts before us it must be self-evident that all attempts to produce malleable iron in a plain cylindrical vessel which has no top to it, and in which the metal rises to within a few inches of its open mouth, must utterly fail from two causes. First, because heat would fly off so freely that the temperature of molten malleable iron could never be reached, and, second, because nearly all the metal contained in such a shallow open-topped vessel would leap out of it, and be scattered in all directions when the explosive eruption takes place, without which no charge of molten pig-iron can be converted into fluid malleable iron. This violent eruption of slags, accompanied by an immense volume of flame which issues from the mouth of the converter, has surprised every one when witnessing the Bessemer process for the first time. Nor was I an exception to the rule, for I was as much astonished as others at this violent eruption, or most assuredly I should never have been so stupid as to design a converter so as to discharge a shower of slag vertically upwards, and thus insure its falling back on to and all around the converter. Till that time no one had ever seen a converter in operation, but no one who had once witnessed the conversion of fluid pig-iron into malleable iron by a blast of air, would ever propose to construct a converter with an opening at the top so as to direct this fiery stream vertically upwards. Later experience allows me fearlessly to assert that a charge of molten crude iron cannot be converted into fluid malleable iron or steel by forcing air through it, without this violent eruption taking place. Hence it is to me utterly inconceivable that any man who had once witnessed the violent eruption invariably accompanying the converting process, should, after such an experience, design and patent a converting vessel with a sloping top and a vertical outlet so admirably adapted to throw upward and discharge so large a proportion of its contents as that shown in Fig. 6, which is an exact reproduction of an authorized drawing of the converter of an American patentee who, it has been asserted, had successfully carried on this converting process many years prior to his taking out this patent in 1857. The original patent is headed: "W. Kelly, No. 505, Re-issued, Nov. 3, 1857."

I had no sooner condemned my first cylindrical converter than I commenced to remedy its defects. The most obvious and ready way of doing this would have been simply to make an opening near the top, on one side of it, and thus allow the escape of the ejected matter to take place horizontally, and direct the discharge against a wall, or allow it to fall into a pit, etc., but I desired to prevent the discharge of metal splashes as far as possible, so that I determined on constructing the new converter with an upper chamber having an arched roof and a conical sloping floor. This converter is represented at Fig. 7 in vertical section, and at Fig. 8 in horizontal cross-section, taken through the tuyeres. When a converter is so constructed the fluid matters which would otherwise pass vertically upward into the air are thrown against the arched roof, and any fluid metal which may be thrown up falls upon the sloping floor of the upper chamber, and again returns to the lower one, while the flame and a portion of the slags find their way out of the two square lateral openings provided for that purpose. This upper chamber serves also as a receptacle for heating up any metal intended to recarburize or alloy with the steel in course of being converted. The section Fig. 8 shows six well-burned fire-clay or plumbago tuyere pipes, fitted to openings left in the lining for that purpose. Their outer ends are made conical to facilitate the ramming in of loam around them, and which effectually holds them in position, and at the same time admits of their easy removal when worn out; a jointed piece of iron tube, with a catch to hold it in place, communicates the blast to each tuyere.

Another view of this converter, taken at right angles to Fig. 7, is represented in Fig. 9, showing in one side the hopper by which the molten iron is run in by a movable

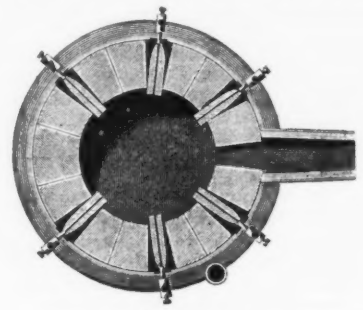


Fig. 8.

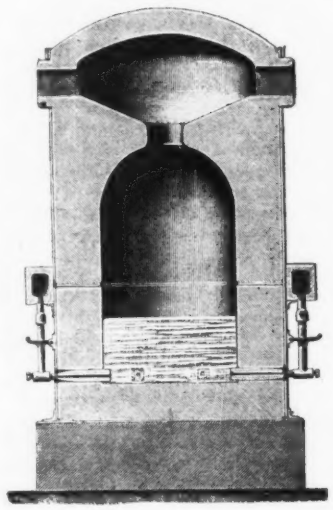


Fig. 7.

Figs. 7 and 8.—Bessemer's Second Converter.

spout direct from the cupola. This view also shows the tapping hole open, and the spout which conducts the converted metal into a movable shallow pan or receiver supported by a long handle (not shown). A fire-brick plug, attached to a long handle, is fitted to a fire-brick ring or opening in the bottom of the pan, and prevents any debris from the tapping hole being carried into the mold.

As this apparatus was intended to exhibit the process, it was essential that an easy way should be provided for getting away the ingots and quickly repeating the process. This casting apparatus, constructed precisely as repre-

sented in Fig. 9, was erected at my bronze manufactory in London about two months prior to my reading the "Cheltenham Paper." It is represented in vertical section Fig. 9. The interior of the mold was 10 ins. square and about 3 ft. in length, and was made in two pieces planed quite parallel and then permanently bolted together. The mold had a massive square lower flange resting on four dwarf columns, which stood on the square upper flange of an hydraulic cylinder. Massive bolts passed through these dwarf columns and through the square flanges, and thus united the ingot mold and hydraulic cylinder, in which a ram or plunger was placed, having a movable square head which accurately fitted the mold and formed a closely fitting movable bottom to it. Both the ram and the external surface of the mold were kept cool by a water jacket provided with supply and waste pipes. Matters being thus arranged, the converted metal was allowed to fall in a vertical stream from the receiver on to the head of the ram. The receiver was then removed, and water under pressure was turned on to the hydraulic cylinder as soon as the steel was solidified, when a beautifully square ingot, 10 ins. square and weighing about seven hundredweight, steadily rose and stood on end ready for removal, the head of the ram rising one or two inches above the top of the mold. There are, no doubt, many persons still living who witnessed this combined converting and casting apparatus in successful operation at my bronze works in London.

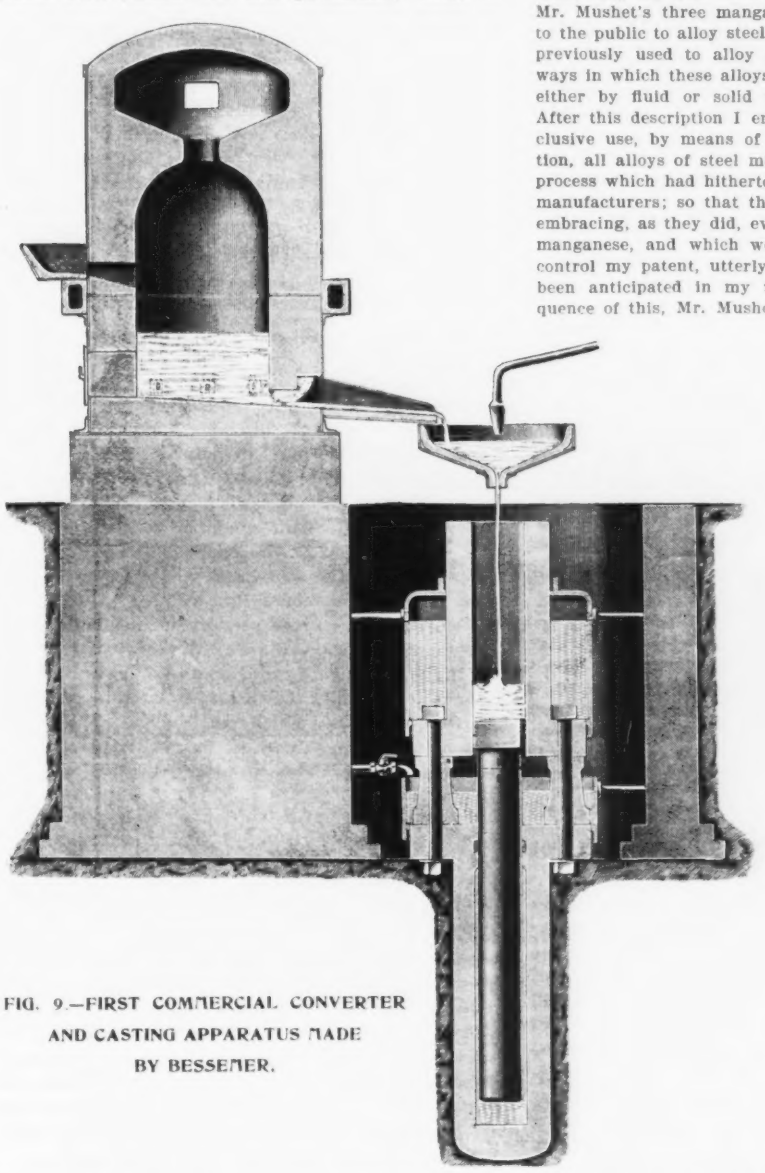


FIG. 9.—FIRST COMMERCIAL CONVERTER AND CASTING APPARATUS MADE BY BESSEMER.

Two ten-inch square ingots made with this apparatus were sent to the Dowlais Iron Works in Wales, and without hammering, were rolled into two flat-footed rails, on Aug. 26, 1856—that is, thirteen days after the reading of the "Cheltenham Paper." They were rolled under the personal superintendence of Mr. Edward Williams, Past-President of the Iron and Steel Institute, where two pieces of these rails are still kept as examples of the early working of my process in London.

I may here call attention to the fact that in my patent, dated Oct. 17, 1855, I described how the state of carburation of the converted metal might be regulated by the addition of molten pig-iron after the blow had taken place; and as this patent was dated eleven months prior to Mr. Mushet's patent, claiming to recarburize the converted metal with the German pig-iron known as spiegeleisen, Mr. Mushet could not prevent my use of that, or any other pig-iron, to recarburize the converted metal after the blow. There was also another absolute bar to Mr. Mushet's claims to the exclusive use of manganese in my process besides its public use in all countries by cast-steel manufacturers, for in another patent of mine, dated May 31, 1856—that is, 16 weeks prior to either of Mr. Mushet's three manganese patents—I gave the right to the public to alloy steel in my process with any metals previously used to alloy cast-steel, by showing various ways in which these alloys might be made in my process, either by fluid or solid metals, or by metallic oxides. After this description I entered a disclaimer to their exclusive use, by means of which disclaimer and publication, all alloys of steel might be made in my converting process which had hitherto been made by other cast-steel manufacturers; so that the three patents of Mr. Mushet, embracing, as they did, every known means of employing manganese, and which were intended to corner me and control my patent, utterly broke down simply by having been anticipated in my two former patents. In consequence of this, Mr. Mushet did not think it worth while even to give me notice that in using spiegeleisen for recarburizing I was infringing his patents, nor did he make any attempt legally or otherwise to prevent me and all my English licensees from the free use of manganese; and I could never understand why American steel manufacturers paid a royalty for the use of these invalid patents.

In this same patent of May 31, 1856, I anticipated the invention of Sir Joseph Whitworth for casting steel under great pressure in order to render the ingots or castings more sound. I stated that

"I have observed that the cellular condition of cast-steel, and more especially malleable-iron castings, is more or less owing to the spontaneous disengagement of gaseous matter in the interior of the fluid mass. Now, it is well known that substances capable of vaporizing, or of evolving gaseous matters, do so with greater difficulty if surrounded by a dense atmosphere. I therefore make use of this peculiar property of matter in order to increase the soundness of ingots or other articles formed by casting in fluid malleable iron or steel."

Then follow details of apparatus both for casting under gaseous pressure and also by the direct action of an hydraulic plunger acting on the fluid steel during its solidification. I have no doubt whatever but that when Sir Joseph Whitworth applied for his patent for casting steel under the pressure of an hydraulic plunger, he was wholly unaware of what I had patented nine years previously, and it is only due to Sir Joseph to say that immediately on his patent agent pointing out this fact to him, he came to me and took a license under my patent, paying me a royalty on all the compressed steel made at his works up to that date at which my patent ceased to exist. That his special mechanical arrangements were an original invention I have never had any doubt whatever, and he had the additional merit of successfully carrying them out.

Before concluding this brief sketch of the more salient points connected with the many forms of apparatus designed by me to facilitate or improve my process, I must revert to the difficulties inseparable from a fixed converter, for in this form of apparatus much heat is dissipated by the necessity of blowing before running in the metal, and—what is still worse—the necessity of continuing the blast after the metal is converted and during the whole time of its discharge. Then there is the uncertainty as to the time employed in tapping, during which time the blowing must be continued, and there is also the difficulty of stopping the process, if anything goes wrong with the blast engine, or if a tuyere gives way.

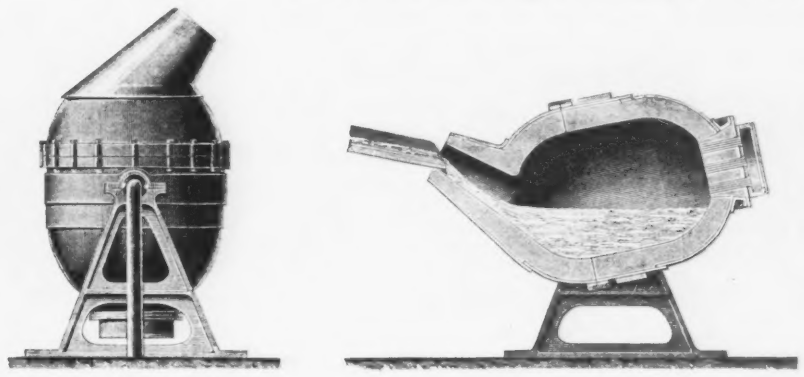


Fig. 10. Fig. 11.

FIGS. 10 and 11.—BESSEMER'S IMPROVED CONVERTER.

These difficulties and many others caused me to search diligently for a remedy for these grave defects, which at that time appeared impossible to overcome, until the happy idea occurred to me of moving the converter on axes, so as to be able to keep the tuyeres above the metal until a charge of molten iron was run in, and which permitted the whole charge to be commenced at one and the same time, and admitted also of the cessation of blowing during its discharge. This movement of the converter also permitted a stoppage of the process to take place at any time for the removal of a worn-out tuyere if necessary, and afforded great facilities for working the process. The peculiar form of the movable converter was a matter of great importance, as there were several necessary requirements to provide for. First, in order to make the heavy lining secure when turned upside down, a more or less arched shape in all directions was necessary, and a long oval form seemed best adapted to the purpose, as it allowed some eight or nine feet in height for the metal to throw itself about in, without leaving the converter. Then the large mouth or outlet pointing to one side was necessary to direct the sparks to be all discharged in a

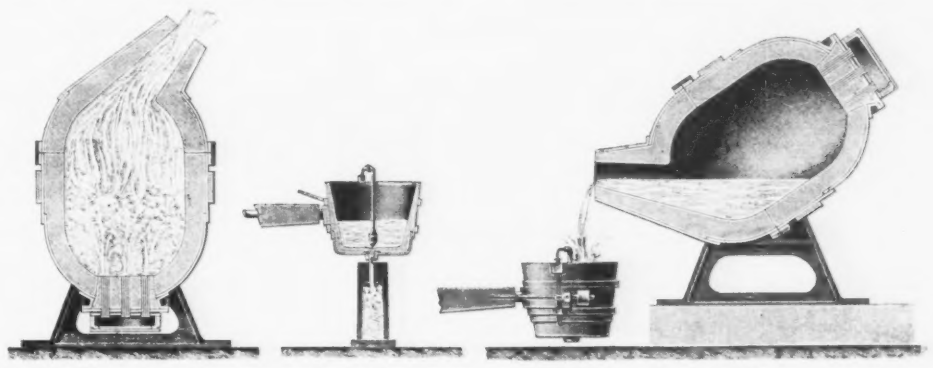


Fig. 12. Fig. 14. Fig. 15. Fig. 13.

Fig. 12.—Position of the Converter During the Blow.

Figs. 14 and 15.—Crane Ladle.

Fig. 13.—Position of the Converter During Pouring.

direction away from the casting pit. After much study the precise form arrived at is shown at Fig. 10, which is an external elevation, and of which Fig. 11 is a vertical section, in the position in which the vessel is retained during the running in of the metal; Fig. 12 shows the position it occupies during the blow; Fig. 13 shows the position is assumes during the discharge of the converted metal into a loamed-up casting ladle provided with a discharge valve at the bottom; the ladle can be moved from mold to mold by closing the valve during such movement, and on opening it a vertical stream descends into the mold, perfectly free from any admixture of slags. The advantage of this mode of filling the molds will be understood when it is borne in mind that the latter are necessarily narrow, upright iron vessels. Now, it is well known that a stream of molten metal, poured from the lip of a ladle, will describe a parabolic curve in its descent, and tends to strike the further side of the mold before reaching the bottom. The surface of the cast-iron mold so struck is instantly melted by the incandescent stream of steel, and the ingot and the mold thus become

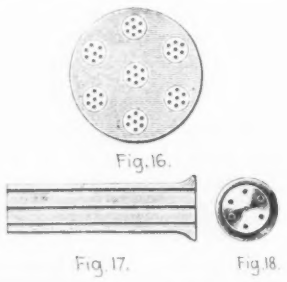


Fig 1[illegible].—Arrangement of Tuyeres in the Converter Bottom.
Figs. 17 and 18.—Section and Bottom View of a Tuyere.

united, causing great inconvenience and destruction to the mold; nor is it easy in pouring the steel from a ladle to prevent some of the fluid slag floating on its surface from flowing over with the steel and spoiling the ingot. All of these difficulties are avoided by the valvular ladle discharging a vertical stream down the centre of the mold, the quantity and flow being regulated with great facility by the hand lever on the side of the ladle.

Many other mechanical contrivances were necessary to perfect the process; such, for instance, as a patent blast engine with noiseless self-acting valves; the hydraulic casting crane carrying the casting ladle over every mold in the semicircular casting pit, and capable of rising and falling to correspond to the descent of the mouth of the converter when filling the ladle for casting. Then there are the direct-acting ingot cranes which clear the pit and refill it with another set of molds rapidly and with little manual labor; then we have the elevated "valve stand," called in America, "the pulpit," from which safe position a single workman can overlook the whole con-

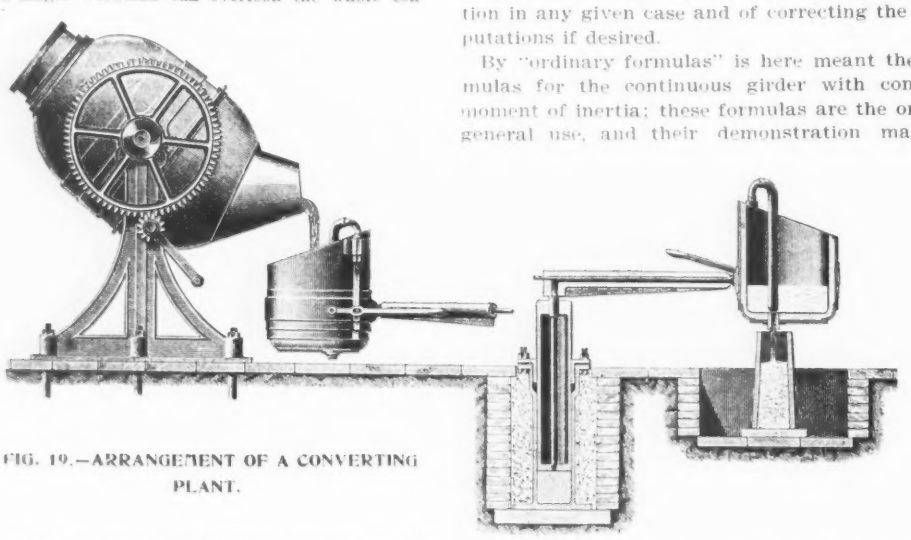


FIG. 19.—ARRANGEMENT OF A CONVERTING PLANT.

verting apparatus, controlling all their movements, governing the blast, working the hydraulic cranes, etc.

The mode of transmitting semi-rotary motion to the converter was another important question which I had to solve. I was of opinion that ordinary shafting and straps were out of the question in dealing with this fiery monster; five or ten tons of fluid metal had to be lifted in one direction, the load diminishing until the fluid running to the opposite end of the converter tended to drive the lifting gear in the reverse direction, so that if anything went wrong or slipped, the converter might swing itself round and discharge these five or ten tons of incandescent steel on to the floor or among the workpeople. This determined me to adopt the hydraulic apparatus now universally employed for governing the motions of the converter, for with this simple and reliable apparatus, a lad at safe distance can start it in motion or stop it instantly, can alter its speed of motion, and control the pouring out of ten tons of incandescent steel as easily as a lady pours out a cup of tea.

The first movable converter was erected at my steel works in Sheffield, and was moved by hand gearing, because at that early date I had not invented the hydraulic apparatus just described. This early converting apparatus did good work at Sheffield, and was constructed precisely as represented in Fig. 19, which shows also the first modification of the hydraulic casting crane, afterwards elaborated and readered suitable for casting heavy charges of steel.

In conclusion, permit me to say that I have great pleasure in bringing before the many eminent engineers of which this society is composed a brief sketch of the early days of this invention, and although many interesting details are necessarily omitted, I trust that I have said enough to show how the Bessemer process originated, and how, by constant study and practical research it was developed from a mere abstract theory, nearer and nearer to a degree of practical development at my bronze works in London till I was justified in erecting the Bessemer Steel Works in Sheffield, which still remain in active operation under the style of Henry Bessemer & Co., Limited. These works were established for commercial purposes and also to serve as a pioneer works or school, where the process was for several years exhibited to any iron or steel manufacturers who desired to take a license to manufacture under my patents; during that time all who desired to do so were allowed to bring their own pig-iron, and personally, or by their managers, see it converted prior to taking a license.

And now, when I contemplate the great steel trade of Europe and America, with an annual production of 10,000,000 tons of Bessemer steel, I may be pardoned if I express some pride and satisfaction when I find that, notwithstanding the keen competition of rival manufacturers and the ceaseless activity and inventive talents of mechanical engineers, my original invention has not been swept away, but still exists in active operation in every steel-making country in the world, intact in all its main features and in almost every detail as it left my hands forty years ago.

THE ACCURACY OF THE ORDINARY FORMULAS FOR SWING BRIDGES.

By. F. E. Turneaure.*

In view of the statements which are occasionally seen, to the effect that perhaps our ordinary formulas for swing bridges may some day be replaced by more accurate and desirable ones, and of various remarks concerning the accuracy of these formulas, it may not be amiss to examine into their accuracy and to point out an easy method of determining the degree of approximation in any given case and of correcting the computations if desired.

By "ordinary formulas" is here meant the formulas for the continuous girder with constant moment of inertia; these formulas are the ones in general use, and their demonstration may be found in any [illegible] on bridges. Furthermore, in this discussion, truss bridges only will be considered.

The method of computation to be explained assumes that the stresses have been determined by some approximate method (preferably by the use of the ordinary formulas) and the sections of the members computed. By this proposed method we may then determine the true reactions and if it is found that those determined by the approximate methods are largely in error the stresses and cross-sections can be corrected accordingly. This would change the reactions to some extent and therefore, in turn, the stresses, but it will be found that the computations need never be repeated for any swing bridge as the second approximation will be abundantly accurate. In fact, it will be shown that the usual formulas are sufficiently accurate in all ordinary cases.

We will consider first a bridge of two equal spans. It will usually be sufficient to make the computations for one case only—that is, for a uniform load covering both spans, bridge acting as a continuous girder. The reactions for this case are determined as follows:

Assume first the bridge loaded with the given load and supported only at the center, both arms deflecting equally. Determine the deflection of the end point by the formula*

$$D = \Sigma \frac{P u l}{E a}. \qquad (1)$$

*For a demonstration of this formula see Johnson's "Framed Structures," p. 220. The method here explained is essentially the same as that used by Prof. Swain in his discussion of the general case of the continuous girder in the Journal of the Franklin Institute, Vol. CXV, 1883.

in which

D = deflection of the end point,
P = stress in any member due to the assumed load,
u = stress in the same member due to a load of 1 lb. applied at the end,
l = length of the member,
E = modulus of elasticity, and
a = area of the cross-section of the member.

Now find in the same way the upward deflection of the end point due to a load of 1 lb. applied upwards at the end. The stress in each member due to this load, and which corresponds to P in the above formula, will be u, the value of which is already known. This upward deflection will then be

$$d = \Sigma \frac{u^2 l}{E a}. \qquad (2)$$

The necessary reaction to produce an upward deflection equal to D, or to bring the end back to normal position, will be

$$R = \frac{D}{d}. \qquad (3)$$

The stresses "P" can be quickly found from a single stress diagram and if the dead load is taken as a uniform load, they will be proportional to the dead load stresses for bridge open. Stresses "u" can also be found from a single diagram, while all other quantities are known. A convenient form for computation will readily suggest itself.

For a symmetrical truss symmetrically loaded it is necessary to sum the terms $\frac{P u l}{E a}$ and $\frac{u^2 l}{E a}$ for one-half the truss only. For symmetrical trusses unsymmetrically loaded we can first assume symmetrical loads and determine the corresponding reactions; then from these get the reactions for the unsymmetrical loading by use of the principle that the moment at the center due to a load on one span is one-half the moment due to two such loads symmetrically placed. Thus, for the case where the first span is fully loaded and the second span has no load, we find in this way the value of the left reaction,

$$R' = \frac{R + \frac{\Sigma P a}{L}}{2}, \qquad (4)$$

in which R is found from (3). L = span length, and Σ Pa = summation of the moments of the loads about the center support.

Since equation (4) holds true when R and R′ are determined by formula, and since Σ Pa is independent of R, it follows that the discrepancy between the values of R′ as determined by deflections and by the ordinary formula is one-half the discrepancy between the values of R. That is, the error in reaction due to the use of the formula is twice as great for bridge fully loaded as for one span only loaded. As these two cases determine the maixmum stresses in nearly all the members, it will not usually be necessary to determine true reactions for other partial loads. However,

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if thought desirable, the reactions can be found for each panel load and the results combined. The additional labor involved is not so great as would seem to be the case, for many of the terms involving P disappear.

For a bridge of unequal spans it is necessary to sum the terms $\Sigma \frac{P u l}{E a}$ and $\Sigma \frac{u^2 l}{E a}$ for all members of the bridge. In this case it is convenient to assume the truss supported at the center and at one end and determine the deflections and reaction at the other.

The foregoing method is applicable not only to a two-span bridge but also to a three-span bridge in which the web members are omitted in the center span or panel; for, assuming such a truss supported at the center, or at the center and at one end, the stresses due to any load are fully determinate.

To get some notion of the accuracy of the ordinary formulas, reactions have been computed for several cases by the above method and also by the use of the formulas; the results are given below. In every case a load of unity per lineal foot extending over the entire bridge has been assumed. The following bridges have been treated:

(a) The Winona Bridge, a description of which will be found in Engineering News, vol. XXVI., 1891, p. 370. A sketch of this bridge is given in Fig. 1.

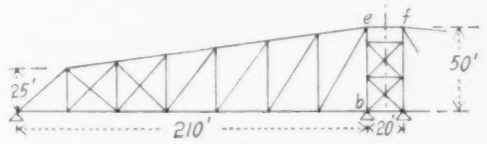

Fig. 1.

(b) A series of designs with the half-truss containing 6, 5, 4, 3 and 2 panels successively. The general dimensions of these truses were chosen by taking a corresponding number of panels of the Winona Bridge. Cross-sections of members were properly determined from stresses due to certain assumed dead and live loads. In each of these cases computations were made for trusses with and without a central panel.

(c) Another bridge of a form similar to the Winona Bridge, but with five 18-ft. panels, a central panel of 18 ft., a center height of 32 ft. and end height of 25 ft.

(d) The Milwaukee drawbridge of the C., M. & St. P. Ry., which is described in the "Engineering and Building Record," vol. XVI., 1887, p. 747. Fig. 2 is a sketch of this bridge.

(e) The Sabula swing bridge as shown in Fig. 3.

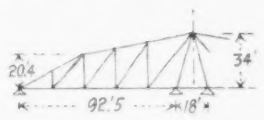

Fig. 2.

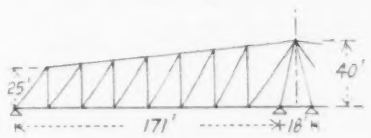

Fig. 3.

This truss is analyzed by Prof. M. A. Howe in his book entitled "The Continuous Girder," p. 72, form which the dimensions of the truss and of the chord sections have been taken. The cross-sections of the web members not being at hand, the required sections have been obtained by computation, making reasonable assumptions as to loads.

The results of these computations are given in the following table:

Truss.	Reaction — True. — (a_1)	(b_1)	By form. — (a_2)	(b_2)	From chords.
a.	64.3	65.9	64.3	67.4	52.9
b. 6 panels.	55.7	57.7	53.1	56.3	44.1
b. 5 "	45.8	47.0	42.0	44.7	34.7
b. 4 "	35.2	36.1	30.9	33.1	25.3
b. 3 "	24.3	25.2	20.0	22.1	14.7
b. 2 "	11.8	11.9	9.4	11.0	8.5
c.	36.8	38.2	34.2	36.7	31.3
d.	44.5	....	47.5	....	39.2
e.	56.6	....	58.1	....	50.9

Columns headed (a) are the reactions for the several trusses with the central panel omitted, while columns headed (b) are the reactions for the trusses having this panel.* The column headed "Reactions from Chords" contains the reactions as determined by deflections, but in the computation of which the chord members are alone considered. These have been figured for trusses without center panel only, and should therefore be compared with columns (a). These reactions are the same as would be found by the use of formulas which take strict account of the variation of the moment of inertia of the truss.

The principal points brought out by this table are: First, the comparatively close agreement between the true reactions and those found by formula, much closer than the writer had supposed would be the case; second, the fact that the formula taking account of the central panel gives results usually more accurate for these cases than the formula neglecting this panel—compare columns (a_2) and (b_2) with (b_1); third, that the reactions found by treating chords only are in every case much more in error than those found by the ordinary formula.

There are in the ordinary formulas two sources of error, one due to assuming the moment of inertia constant, and the other due to neglecting the distortion due to the web members. A decrease of moment of inertia towards the end of the truss tends to decrease the reactions while the effect of the web members is the reverse. This is clearly brought out by the table. The resultant effect is, however, small, at least in the examples given, and the statement appears to be warranted that the ordinary formula will give more accurate results than a formula involving variable moment of inertia, and that in most cases the results given by the former are sufficiently accurate. If it is desired to know the error in any case it can be readily found by the method here explained and corrections made accordingly.

The neglect of web distortion gives rise also to very erroneous conclusions in regard to the action of diagonals in the center panel of a three-span swingbridge. We will find our previously computed deflections of assistance in discussing this question.

Take for example the Winona Bridge and let us see what will be the effect of unsymmetrical loads on the bracing of the center panel, assuming this bracing to be attached at points e and f instead of lower down. The maximum distortion, or horizontal movement of the point e, will occur when the first span only is loaded. Assuming a uniform load of 3,000 lbs. per ft. on this span, the right reaction is found to be —19,000 lbs. Referring now

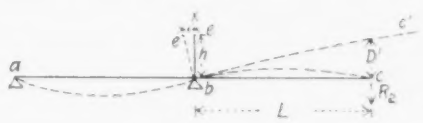

Fig. 4.

to Fig. 4, let the full line a b c represent the axis of the bridge before the load is applied, the dotted line a b c the axis afterwards, and b c' the tangent to this line at b. The horizontal movement, x, is evidently equal to $D' \times \frac{h}{L}$. The deflection D', will be equal to the reaction R_2 multiplied by the deflection d (due to 1 lb.) as previously found. Or, in this example, d having been found equal to .0000334-in., we have

$$x = .0000334 \times 19{,}000 \times \frac{50}{210} = .15\text{-in.}$$

The vertical movement of the point e is that due to the stress in the member e b. This stress being 154,000 lbs. and the area of the section of the member 33 sq. ins., the vertical movement

$$= \frac{154{,}000 \times 50 \times 12}{30{,}000{,}000 \times 33} = .093\text{-in.}$$

*The formula used for column (b) will be found demonstrated in Johnson's "Framed Structures," second and succeeding editions, p. 194, and in Engineering News, vol. XXXIV., 1895, p. 150.

In Fig. 5 is represented the center panel. The length of the diagonal is l, and the panel length, p. Differentiating the equation

$$l^2 = p^2 + \left(\frac{h}{2}\right)^2$$

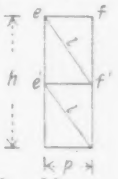

Fig. 5.

with respect to both p and h, we have

$$2\,l\,d\,l = 2\,p\,d\,p + 2\,\frac{h}{2} \cdot \frac{d\,h}{2},$$

whence

$$\frac{d\,l}{l} = \frac{p\,d\,p + \frac{h}{2} \cdot \frac{d\,h}{2}}{l^2}, \qquad (5)$$

that is, applying this equation to the lower panel, the elongation per unit length of the diagonal

= (p × horizontal movement of e' + $\frac{h}{2}$ × vertical movement of e') ÷ l^2,

in which an upward movement of e' is positive. In the present case, both horizontal and vertical movements of e' being one-half those of e, we have

$$\frac{d\,l}{l} = \frac{20 \times 12 \times \frac{.15}{2} - 25 \times 12 \times \frac{.093}{2}}{(20 \times 12)^2 + (25 \times 12)^2}$$

Multiplying this by 30,000,000, the modulus of elasticity assumed in the other computations, we have finally the unit stress in the diagonal = 830 lbs. per sq. in., tension, a result independent of the size of the member. The stress in the upper diagonal will be somewhat less since the point f' does not move downwards as much as e'. If h were 64 ft. instead of 50 ft. there would be no stress in the diagonals. In many cases the diagonals are much more inclined to the horizontal than in this case and the stresses are correspondingly small or even compressive. This is true in several of the trusses described in this article.

It has usually been assumed that heavy diagonals in the center panel cause the bridge to act as a beam would act when resting on four supports, or at least that such diagonals seriously interfere with the use of the formula for a two-span bridge. The results so far obtained by the method here given would seem to show that as large diagonals may be used as is thought necessary and then entirely neglected in the computations. If the diagonals are stressed, then the horizontal and vertical movements will be slightly modified thereby, which in turn will decrease the stresses in the diagonals. Hence the stresses found as above are greater than those actually occurring.

A very important question, and one of especial significance when discussing accuracy of formulas, is that of the effect of a variation of temperature between different members of a swing-bridge. The effect on reactions of any given difference of temperature can very quickly be found from our previous computations.

Let

t = change of temperature of any member,
c = coefficient of expansion, = .0000065 per 1° F.,
l = length of member.

Then c t l = total change of length of any member. The deflection of the end of the truss due to the change of length of this member will be u c t l, where u is the same as in our previous work, and for a change of temperature of any number of members the deflection,

$$D_t = \Sigma\, u\, c\, t\, l. \qquad (6)$$

The reaction necessary to produce a like deflection, or the reaction produced by the assumed temperature changes will be

$$R = \frac{D_t}{d}, \qquad (7)$$

in which d = deflection due to a one-pound load, as before. For example, suppose the lower chord of the Winona bridge to drop in temperature 1° F. In this case c t l for each member = .00234 and Σ u = 20, whence

$$D^t = .047 \text{ and } R^t = \frac{.047}{.0000334} = 1{,}400 \text{ lbs.},$$

a very large amount for a change of temperature of only 1°. Considering a possible difference of temperature of 30° or even more, the great effect of this element can be appreciated. The effect is so great as to evidently render much refinement in calculation entirely useless and to support the statement previously made that the ordinary formulas are accurate enough for all ordinary cases.

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In view of the annual convention of the American Society of Irrigation Engineers to be held at Denver next week, and the National Irrigation Congress to be held in the week following at Phoenix, Arizona, we this week devote an unusually large proportion of our space to papers on irrigation engineering, and in order to do this without encroaching on the space allotted to other departments of engineering, we have added eight extra pages to this issue. The tables by Mr. Pope, for the flow of water over weirs, which are given in this number, will be found useful, we believe, by hydraulic engineers generally as well as by those who desire to measure water for irrigation purposes. For the benefit of any of our readers who may desire to have these tables in a shape more handy for use, we would say that they are to be published by the author very shortly in a convenient pocketbook form.

In our correspondence column this week we publish a letter from Mr. Josiah Pierce, Jr., concerning the topographical survey of the City of Baltimore, and we ask the careful attention of our readers to its contents. This letter was written in reply to one stating the grounds upon which we made our recent comments on the work of this survey, and it should be read in connection with the statements made in the expert's report in our issue of Nov. 12. Our criticism in that issue upon the methods of obtaining data for the detail maps, was based upon information gleaned from the official proceedings of an investigating committee appointed by the City Council of Baltimore. These proceedings stated that Mr. Pierce, as acting chief of the survey, and other officers of the survey had been before the committee in their own defence; and that reputable expert witnesses, like Major N. H. Hutton and Mr. O. H. Tittman, the latter of the U. S. Coast and Geodetic Survey, had testified in support of the report of the committee. We assumed that the investigation was fairly and honestly conducted and criticised the reported results accordingly.

From the letter of Mr. Pierce, and from other recent information furnished us, it would now seem that the manner and methods of this investigation are themselves open to criticism, and that the whole subject is to be submitted to another board of experts, of such professional experience and reputation as to leave no doubt as to the accuracy and honesty of the verdict to be rendered. We regret that the nature of the evidence previously submitted should have placed us in the position of possibly doing an injustice to engineers who have certainly done exceptionally good work in a great part of this survey. And under the newly developed conditions we can only ask our readers to await the more exhaustive report referred to before passing final judgment upon the work of those in charge of the Baltimore topographical survey.

The paper by Sir Henry Bessemer, presented at the meeting of the American Society of Mechanical Engineers, which we print in full on another page, is one which will be found of great interest, as being probably the clearest account of the details of the work done by the eminent inventor which has ever been published. We regret, however, that Sir Henry has seen fit to include in the paper some matter which is outside of the description of his own work, and which tends to detract from the credit which should justly be given to other inventors in this field, especially Heath, Kelly and Mushet. For the sake of the truth of history it is desirable that the work of these men should not be allowed to fall into oblivion and their credit be hidden by the overshadowing fame and honor which Bessemer has deservedly obtained. Some of the history of the origin of the Bessemer and open hearth process has for many years been a matter of controversy, and it seems only fair for us to give in connection with Bessemer's account a statement of some of the evidence which tends to show that while Bessemer is justly entitled to the credit he has received, some credit also is due to others, which he seems inclined in his paper to withhold.

The first statement to which we would call attention, relates to Bessemer's connection with the open hearth process Sir Henry says:

> As far back as January, 1855, I had claimed in my patent the fusion of steel in a bath of melted pig or cast-iron in a reverberatory furnace, as herein described. * * I think I am justified in saying that the fusion of steel in a bath of pig iron, on the open hearth of a reverberatory furnace, which I had patented and successfully effected, was, to use a favorite expression of Mr. Gladstone, "approaching within measurable distance" of that now well-known and successful process.

The fact is that the fusion of steel in a bath of cast iron on the bed of a reverberatory furnace had been practised in England and described long before 1855. In Hasenfratz's "La Siderotechnie," Paris, 1812, Vol. IV., pp. 93-99, there is described the method of manufacturing two varieties of steel, known in England as Marschall and Huntzmann steels. It is stated that

> A mixture of gray and white cast iron is made. Sometimes also there is mixed either with the gray cast-iron alone or with the mixture of these two cast irons, clippings of iron, old bar iron, scales and even clippings of steel. The mixture described to make the second kind of steel is melted in ordinary reverberating furnaces in which one has prepared a sort of crucible in the lowest position. As soon as the cast iron begins to refine itself the principal workman introduces a small spoon into the bath. He continues to take out tests until that which he withdraws can be forged; then he examines the grain of the steel; if it is too soft the workman throws into the bath bars of steel too much cemented, which gives it carbon without altering its refining. If it is too hard he throws into it clippings of iron—sometimes even of bar iron—to diffuse the carbon through a larger mass or to burn a portion of it; then he withdraws the slags; he runs the cast-steel into the molds and it is afterwards forged to be sent forth into commerce. The facility which they have in England of procuring scraps to melt for steel gives to the inhabitants of that island a considerable advantage over all the other nations of Europe.

In the "Dictionnaire des Arts et Manufactures," Paris, 1845, A-F., p. 48, it is stated that

> M. Breant has proposed two different processes for directly manufacturing cast steel. In the second process one oxidizes on the hearth of a reverberatory furnace a certain quantity of good pig iron to which one mixes subsequently an equal quantity of the same nature, but not oxidized. On stirring well the materials the whole soon goes into fusion and furnishes a steel of good quality.

Josiah Marshall Heath, English Patent No. 10,798, of 1845, describes a process for the manufacture of cast steel on the bed of a reverberatory furnace, and states that the furnace may be heated by gas formed in a separate gas producer.

> The interior of the furnace should be kept at the highest temperature that can be produced. A bath of cast iron is formed on the bed of the furnace and it is refined by the addition to it of malleable iron in scraps or in any convenient form, or of iron which has been made from iron ore by cementing it with carbonaceous matter at a red heat in a close vessel.

It is thus seen that the fusion of steel with pig iron on the bed of a reverberatory furnace, for the purpose of making cast steel was known at least as early as 1812; that the fusion of pig iron, together with oxidized pig iron (that is, wrought iron), on the bed of a reverberatory furnace for the purpose of making steel was described in Paris in 1845; that Heath's process for making cast steel differs in no respect from that described by Bessemer, except that it states "the addition of malleable iron," instead of steel. But steel was used in a bath of cast iron, as already stated, as early as 1812.

All the early attempts to make steel on a reverberatory furnace by the mixture of cast iron and of wrought iron or steel seemed to have failed commercially prior to 1855 for three reasons:

(1) The lack of the Siemens regenerative furnace, (invented by Frederick Siemens, brother of Charles William Siemens, in 1856), or of any furnace which could produce and steadily maintain the temperature necessary to hold in fusion iron low in carbon.

(2) The want of knowledge how to overcome red-shortness, which was not known until Mushet described the use of spiegeleisen, in 1856.

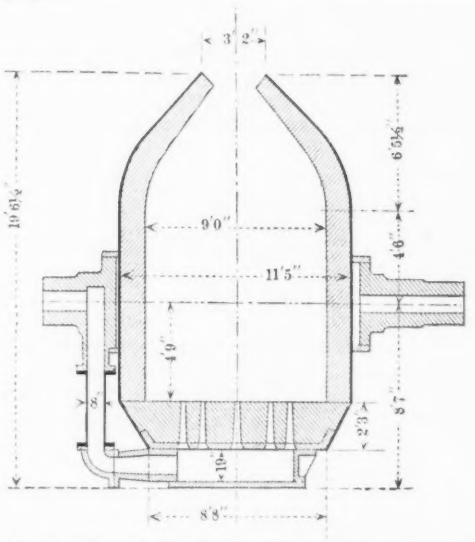
(3) The lack of knowledge of the chemical composition of pig iron required to make good steel.

Bessemer, therefore, in 1855, was not "within measurable distance" of the modern open hearth process any more than Heath was, who anticipated him in date by nearly 10 years.

The next point raised by Sir Henry Bessemer which is open to criticism relates to the converter of Kelly, and to Kelly's claim to priority of invention of the pneumatic process. He says:

> No one who had once witnessed the conversion of fluid pig-iron into malleable iron by a blast of air, would ever propose to construct a converter with an opening at the top so as to direct this fiery stream upwards. It is to me utterly inconceivable that any man who had once witnessed the violent eruption accompanying the converting process should, after such an experience, design and patent a converting vessel with a sloping top and a vertical outlet so admirably adapted to throw upward and discharge so large a proportion of its contents as that shown in Fig. 6.

It appears that the converter now used in the most modern American works is exactly of this description; it has a sloping top and a vertical outlet admirably adapted to throw up and discharge its contents. On p. 63 of Mr. Harry Huse Campbell's recent work on "Structural Steel," is shown a sectional view (which we reproduce herewith)



18-Ton Converter in Use by The Maryland Steel Co., 1896.

of an 18-ton converter, used in the works of the Maryland Steel Co., at Sparrows Point, Md., which has the sloping top and the vertical outlet.

Referring to the claims made on behalf of Robert Mushet, Sir Henry states that he (Bessemer) described in his patent of Oct. 17, 1855, how the state of carburation of the converted metal might be regulated by the addition of molten pig iron after the blow had taken place, and as this patent was dated 11 months prior to Mr. Mushet's patent, claiming to recarburize the converted metal with the German metal, known as Spiegeleisen, Mr.

Mushet could not prevent the use of that or any other pig iron to recarburize the converted metal after the blow.

But the fact is that Mr. Mushet's patent of Sept. 22, 1856, clearly shows that the effect of the addition of spiegeleisen was not merely a recarburizing but also a deoxidizing of the bath. Mushet says in his provisional specification:

> When cast-iron has been purified or decarbonized by blowing air through it when in the metal state, it is difficult to convert it into malleable iron or steel. I have discovered that by combining such purified iron in a heated state with a triple compound consisting of or containing iron, manganese and carbon, also in a heated state, I can obtain malleable iron or steel.

In his complete specification he describes at length the difficulty referred to and describes the product of simple decarburizing as "red short" or "hot short," and says the ingots so made are also generally porous or cellular in structure. He says further:

> To the purified cast iron when it has become wholly decarburized or nearly so by the action of air forced into or among its particles whilst it is in a molten or fluid state, I add a triple compound alloy or material of or consisting of iron, carbon and manganese, which mixture I effect in any suitable furnace, vessel or ladle. * * * I prefer to use the white crystalline cast-iron metal thus obtained and known in Prussia as spiegeleisen—and I prefer to use such varieties of this white crystalline cast-iron metal as are found to contain a large alloy of manganese.

Mushet further states:

> As the triple compound of or containing iron, carbon and manganese parts with a portion of its manganese every time it is remelted, I prefer to use that which has not been previously remelted and I avoid as much as possible any repeated remelting of it.

Mushet's claim is "the addition of a triple compound or material of or containing iron, carbon and manganese to cast iron which has been purified and decarburized by the action of air whilst in a molten or fluid state, or in any convenient manner."

Sir Henry Bessemer classes "the German pig-iron, known as spiegeleisen," as being simply a particular kind of pig iron. It is, nevertheless, as different a material from what is ordinarily called pig iron in commerce as ordinary pig iron is different from tool steel, or tool steel from wrought iron, in appearance, in chemical constitution and in physical properties; and spiegeleisen moreover differs wholly from pig iron in containing metallic manganese, which has the peculiar property of overcoming the red-shortness of steel. Sir Henry further says: "I never could understand why American steel manufacturers paid royalty for the use of these invalid patents" (that is the Mushet patents). The fact is the Mushet patents were not invalid in America, and it is very doubtful if they or the Kelly patents could have been made invalid by litigation. In 1865 the Kelly Process Co., owning the U. S. patents of Kelly and Mushet, and Winslow, Griswold & Holley, owners of the American Bessemer and Holley patents, concluded that it would be better to combine their interests than to enter into expensive litigation, and a combination was effected on the basis of 70% of the royalties going to the owners of the Bessemer and Holley patents and 30% to the owners of the Kelly and Mushet patents. (See Robert W. Hunt's "History of the Bessemer Manufacture in America," Trans. Am. Inst. M. E., Vol. 5). The owners of the American patents granted to Bessemer and Holley in 1865, no doubt considered there were strong reasons for believing the Kelly and Mushet patents to be valid, or they would not have entered into such an agreement.

THE OWNERSHIP AND CONTROL OF WATER IN THE IRRIGABLE WEST.

The saying, WATER IS KING, is as popular and well-warranted in the Irrigable West to-day as was ever the same ascription to cotton in the South. In fact it has more complete sovereignty, and that over a far more extended area, than was ever true of cotton; for at best cotton shared its rule with sugar, rice, corn and tobacco, as well as minor crops, while upon water, artificially applied, depend all crops in the West, and thus to a large extent all material progress. To carry the idea of the kingship of water a little further, it may be said that the monarchy is a limited rather than an absolute one, operating under both written and unwritten constitutions which are determined by the real and higher sovereigns, the people. This brings us directly to the question which it is the purpose of this article to discuss, the ownership and control of water in the Irrigable West. The region designated as the Irrigable West is meant to include all the Western States, where the culture of the land is dependent on irrigation, rather than the comparatively small areas which are actually irrigable. The question is many-sided and intricate. It will be possible for us to discuss only some of its broader phases which, governing the development of the country through the building of irrigation works, are intimately connected with the character of such works, and therefore deeply interest and affect engineers and contractors.

First, it may be said that as all cultivation of the land in many sections of the West is absolutely dependent on irrigation, ruin continually menaces agriculturalists unless they can be sure of an unfailing and ample supply of water at a reasonable price. Next, it should be noted that there is not enough water to supply all the arid land that is within reach of the streams, and hence the available supply must be most judiciously developed and conserved, and, equally important equitably distributed. Finally, economy demands that many or even most irrigation works be carried out on so large a scale as to make construction impossible except by large private companies or at public expense, while the sums of money thus involved are subjected to great risks unless a good market and sure pay can be obtained for the water developed.

The gist of the whole matter is, water and land must be wedded, each being well suited to the other, and having been once united never be divorced under any pretext, but always live amicably together with a due regard to economy of use and the rights of neighboring lands.

All this seems simple enough in the abstract, but the practical application of these principles sometimes bid fair to divide the irrigable territory aganst itself, while at least one of the problems involved, the public land question, may yet become the cause of a temporary bitter feeling between East and West. Certainly such feeling is likely to arise unless the East informs itself much more fully than it yet has regarding the various aspects of the question, and unless the West continually bears in mind that the remaining public lands are as much as ever a national possession, and not wholly of local interest and importance.

A few facts regarding the present status of both the public lands and the water problem may be given here. These points are some of many salient ones brought out by Mr. Elwood Mead, M. Am. Soc. C. E., State Engineer of Wyoming, in a paper to be read before the meeting, next week, of the American Society of Irrigation Engineers.

It will come as a surprise to many in the East to realize that the great bulk of the area west of the 100th meridian, is public land, owned by the United States, and not subject to taxation, therefore, by the states themselves. No less than 84% of the entire area of the nine states enumerated below is public land. Thus, these nine states as a whole have to maintain a law and order over a territory of which only 16%, on the average, is subject to taxation for either state or local purposes, or subject to the irrigation laws which the separate states may enact.

State.	Total area, sq. miles.	—Taxable area,— sq. miles.	per cent.
Montana	145,310	16,196	11.14
Idaho	84,290	5,708	6.77
Wyoming	97,575	6,051	6.20
Colorado	103,645	30,104	29.04
New Mexico	122,460	29,688	24.24
Arizona	112,920	6,634	5.87
Utah	82,190	7,812	9.51
Nevada	109,740	3,906	3.55
California	155,980	56,445	36.19
Total	1,014,110	162,544	16.03

These figures are very significant as showing the vast areas of the public domain in these nine states: the comparatively small area under settlement, taxation and state control generally, including irrigation matters; and the slow rate at which these conditions are changing.

By an act of 1894, each of these states may have transferred to it 1,000,000 acres of the public lands, under certain conditions looking to reclamation by irrigation. Five states have accepted the grant, but only one, Wyoming, has proceeded sufficiently far to select and secure the approval of the area donated, and none of this land has yet been transferred to actual settlers. Mr. Mead urges that the conditions of the grant are not conducive to the best results, and, while apparently welcoming the move as a step towards a proper solution of the problem, considers it as only a step. One condition of the grant he most heartily approves, and that is the making the right to the use of water inalienable from the land reclaimed by it.

Having extracted the above from Mr. Mead's paper a return may be made to the general subject under discussion.

The water problem has been solved, or left to a large extent unsolved, as each of the Western States has seen fit. In many of these states, if not all, the water has been considered as public property, but it has been subject to appropriation for use in irrigation under legislative enactments.

Such appropriation has the effect, to a greater or less extent, of making the water private property, and sometimes of giving it a speculative value, this speculative quality depending on the character of the appropriation laws and the manner in which they are administered. These statements do not apply to the water flowing through the public lands of the several states. The general government does not, and the state governments cannot, at present control such water supplies. Consequently water appropriations may be and are made with utter disregard to any interest but self interest, often to the great detriment of existing and future settlers. When the vast areas of public lands yet remaining are taken into account, the importance of establishing control over the water supplies pertaining to the public land becomes apparent. Of course only a small percentage of the public lands is irrigable, but the water rights on a far greater proportion of the land have a definite relation to the irrigable area, while, as Mr. Mead points out in the paper mentioned above, the condition of the forest areas vitally affects the water supply, and the administration of grazing lands has a direct bearing upon the prosperity of irrigators.

From the above, it is evident that the water question and the public land problem are most intimately connected. If all remaining public lands were to be turned over to the several states within which it is located, the water would go with it, and thus come under present state laws, unless the grant contained conditions to the contrary. If the national control of land is continued there will confrom many of those who believe in state control, over vast areas, unless a change of policy is inaugurated by Congress. Such a change would probably have to be sweeping to be of any effect and would meet with much opposition, notably from many of those who believe in state control as postponing that, and from those who have profited by the past and present let-alone principle.

To discuss adequately these great land and water questions would require a careful study of the history of our public land system, and of the water legislation of the several states, together with the practical working and results of each. This is, of course, far beyond the limits of the present article, and we may add that the magnitude and far-reaching importance of these questions is scarcely dreamed of by most of the people of the East, and fully appreciated by only a limited number in the West.

What we wish to do now is to call attention to this great Western problem and point out some of its main factors. This we have attempted to do above. We shall conclude by stating briefly the governing principles which seem most clearly established and freest from controversy, as follows:

(1) The agricultural products of the so-called arid region are its greatest source of wealth, and upon these all other industries and all progress are dependent.

(2) Irrigation is essential to agriculture in this region, and both depend for their success upon the wise solution of the great land and water questions.

(3) The public lands have long been regarded as the Nation's heritage and safety, but their value depends upon the public water supplies, so each

should be equally held in trust for the people and neither should become subject to speculative control for private profit.

(4) While speculative profit should be prevented, capital and labor must each have its legitimate reward.

(5) Economy of construction and operation demands that many irrigation works should be built on a large scale, to water great tracts. The volume of capital thus required renders the enterprises risky, and tends to the establishment of high water rates in order to produce returns commensurate with the risk, while at the same time the water company often controls the only available source of supply, and thus is tempted to demand high rates, whether or not the risks involved warrant them.

(6) As the uses to which land may be put, and thus its value, depend upon the amount of water available, and, moreover, as land without water is only a drug on the owner, the construction of irrigation works should precede, or at least accompany, the settlement of the land.

(7) As there is not enough water for all the land, the water should be conserved with the utmost care, and the land to be watered chosen with equal consideration. Water conservation includes the preservation of forest areas, the development of the greatest possible percentage of the rainfall, a minimum loss through evaporation and percolation, and a wise application to crops. It may even go farther in some cases and include the reclamation of the seepage water from irrigated areas.

(8) As the land and water are mutually dependent for value, and the water development comes first, and must be made to suit the land, evidently their development under joint ownership or some common regulation is desirable. This, we believe, has been done very advantageously in California under the Wright Irrigation District law, where the land owners build and own the irrigation works. The same plan has more recently been adopted by other states, and bids fair to gain in favor now that the U. S. Supreme Court has upheld the California statute.

In closing, attention must be called to one phase of the water problem of the public lands which seems to be almost wholly overlooked in the discussion of the subject, but which in many sections has not escaped investors, the value of natural water powers. . We cannot enlarge upon this subject at present, but throw out the question, should not the national government, or, if the lands are turned over to the states, the latter, retain control of the water powers, leasing the right to use them under proper conditions? The aggregate value of these rights is great. Does not the principle, all water should be held as public property, adopted by so many Western states, apply to water for power as well as for irrigation? Just now irrigation is uppermost in many sections, but the time will come when water power will be in great demand, a fact that should be borne in mind by all concerned.

LETTERS TO THE EDITOR.

Scherzer Rolling Bascule Bridge for Newtown Creek.

Sir: I desire to call your attention to some of the reasons why I found it impossible to present a complete design of a Scherzer rolling bascule bridge, adapted to the locality, within the 20 days limited by the joint committee on bridges of Kings and Queens counties, in their advertisement requesting designs for a new bridge to be built at Vernon Ave. across Newtown Creek.

The advertisement called for drawings showing the general design of the proposed structures with length of movable span or spans, and of stationaries, if any, width of clear waterway, width of roadway and of footways, loads proposed to be sustained and carried, dimensions of all the parts, and modes of construction and strain sheets showing the forms and construction of typical members with strains sustained. Also the metals proposed to be used, style of flooring and motive power, with sufficient detail to indicate the manner of the application and operation of the same, and a type-written description of the proposed structures. Each design to be in accordance with the regulation of the U. S. War Department.

The data given in the advertisement and that supplied upon application to the engineer designated was very inadequate, and I found it necessary to visit the site of the proposed bridge and there carefully study the situation, and the highway and water traffic to be accommodated. I also found it necessary to have a survey and map made of the vicinity of the bridge.

A careful study of the situation convinced me that any bridge at the level of the present swing structure would be a very poor solution of the problem, as the old bridge is opened from 100 to 200 times in 24 hours at the present time; and this large amount of navigation is constantly increasing. Such a low-level structure would be more expensive to operate, and would afford no accommodation to the large highway travel across the bridge, as it would have to be opened for every passing craft. If built it would at once necessitate the building of more new bridges to afford relief.

The low bridge would be in constant danger of being struck by the hulls of heavily loaded vessels, and greatly injured thereby, for the current caused by the tide is very strong in Newtown Creek, and vessels are frequently uncontrollable. Great delays and constant exposure to accidents would also result from the grade crossing of the Long Island R. R. tracks, which are about 200 ft. from the bridge, and form a very serious interruption to traffic.

Believing that the citizens and taxpayers who would have to pay for the new bridge wished to have the best structure to be obtained, I expended, gratuitously, a large amount of time and money to prepare the design which I submitted to the bridge committee. It required more than 20 days to prepare my design, and I believe that is one reason why it is especially worthy of consideration.

The design consists of: (1) A Scherzer rolling bascule bridge placed sufficiently high to allow about 70% of the water traffic to pass beneath without opening. (2) A viaduct which affords a safe and continuous overhead passage across the tracks of the Long Island R. R. The only objection to a viaduct would be that of a few abutting property-owners, but as the larger part of the abutting property is at present unimproved, the objection could not be serious, for many of the most prominent streets of Brooklyn are occupied by elevated railway structures, which are certainly more objectionable than a short viaduct in a less important street. However, should the viaduct be dispensed with, the bridge ought still to be elevated and be reached by short approaches. (3) The bridge is not an experiment, as it is similar to the two Scherzer rolling bascule bridges now in successful operation at Chicago, and also similar to the new Scherzer bascule bridge at North Halsted St., Chicago, rapidly nearing completion. The latter bridge is 50 ft. 2 ins. wide; has a clear opening between piers of 121 ft.; is designed to carry the heaviest electric car and highway traffic, and with the approaches is 327 ft. long. It cost complete, including approaches, machinery, and electric equipment, only $113,425, less than one-half as much as the Waddell lifting bridge, located upon the same street, upon the south branch of the Chicago River. (4) The large Scherzer bascule bridges are opened or closed in less than 30 seconds; and a similar Scherzer bridge across Newtown Creek would be operated in the same time. (5) The bridge requires no center supports or piers. It does not encroach upon valuable dock room; and when opened it closes the highway absolutely, thus preventing accidents. (6) It is economical in construction, as it only requires sufficient material to bridge the chasm, and dispenses with expensive towers, ropes, cables and movable counterweights. (7) It forms a very rigid, simple and artistic arched structure, adapted for the heaviest traffic, and wherever it has been tested it has given complete satisfaction. (8) It can be completed to work successfully in less than one year, and during its erection does not interfere with navigation.

I believe that a final decision has not yet been made, and hope that the ultimate decision will be solely upon the merits of the various designs. Yours very truly,

Albert H. Scherzer.

Chicago, Ill., Nov. 23, 1896.

The Topographical Survey of Baltimore.

Sir: In reply to your letter of the 20th inst., regarding the investigation of the topographical survey of the city of Baltimore, I am not surprised that you have been misled as well as others by the reports you have examined, as they contain statements which will not bear analysis.

I cannot make this point clearer than by calling your attention to the report of the survey, published January, 1895, in which you will find illustrations, upon a reduced scale, of property maps, upon which all dimensions are given in feet and decimals, based entirely upon locations of all details by transit observations and steel tape measurements. There exist about 150 such maps in the office and 100 note books containing the records of field measurements from which these maps were drawn, as well as innumerable notes and computations bearing upon the use of these notes in the problems involved in the analysis and adjustment of property and street lines.

There exists no evidence that the telemeter-rod has been used beyond its legitimate and economic use in topographical work, under well-known conditions and limitations, in spite of the assertions of Messrs. Sudler and Donn to the contrary, and the denial in their report of the existence of any such records as I have described.

It needs no expert examination of the published maps to show that they do not contain dimensions and lengths, "in feet and inches," etc., nor of the unpublished maps to show that they do contain the desired information and that they could not have been drawn and the dimensions given from telemeter readings.

The committee chose to disregard the requests made to examine the work as a whole and failed to verify the testimony given by the engineers of the survey, either by their own personal examination of the records and unpublished results, or by bringing this evidence to the attention of witnesses. It consequently lay in the power of this committee, by their presentation of their report to the city council without granting the opportunity which was requested for a defence to be made, and by withholding from examination the report of Messrs. Sudler and Donn, to very seriously influence public opinion, particularly by the publication of the latter report in the press before any of the testimony taken had been examined or officially acted upon by the commission authorized to conduct the topographical survey.

It is impossible for any fair-minded person to regard such reports as unbiased or expert when overwhelming evidence exists in the records of the survey to show that their foundation rests upon falsehood.

Major Hutton, Mr. Tittman and others, being unfamiliar with what had been done, with the problems involved, and with the progress made, and having upon no occasion examined the office work of the survey, were called upon to answer categorical questions, and were not called upon to discuss that section of the ordinance which provides for the publication of the topographical maps, nor the act of the State legislature, which gave the authority for their publication, consequently their testimony carries little weight.

It should be borne in mind that the work proceeded for 2½ years without interruption, with full authority for every step taken, and that complete records of all measurements, notes and drawings exist. In addition, during the current year, appropriations were granted for the continuation of the property work of the survey, designed for tax valuation and other purposes, outlined in the ordinances, including all of those details not carried in the topographical maps.

The latter maps were never intended to have street widths, etc., given upon them, because they were designed for use mainly in the annexed portion of the city, covering an area of 17 sq. miles, over the greater portion of which no streets exist; for the study of street lines and grades and their extension over the entire city, and their publication, before full information could be given on a larger scale of the details of the property work, was a necessary consequence of their requirement for the study of drainage. The charge that these maps are inaccurate and unreliable is untrue in view of their having fulfilled every requirement for which they were designed, and they are as free from mistakes and errors of appreciable magnitude as could possibly be expected with an average of 7,000 locations and elevations per sq. mile.

The investigation was first requested by Colonel Douglas before a board of competent experts, and the consent of the superintendent of the U. S. Coast and Geodetic Survey, the director of the U. S. Geological Survey and the Chief of Engineers of the U. S. Army, was obtained to appoint such a board, if called upon to do so officially, but the opportunity was denied. We have now demanded the right to present our statements before a competent board, and it is no longer our purpose to defend what we know to be right, but to show that the reports made are neither expert nor professional.

This will probably occur in a week or ten days, when a very full exposure of the entire matter will be given by Colonel Douglas, myself and others.

From a technical standpoint quite a number of important questions have arisen in this discussion, notably in the assumption of Mr. Donn that the principles of geodesy had been ignored by the adoption of a central meridian, and the computation of positions by rectangular coordinates with which he has shown his unfamiliarity.

He asserts that the instruments placed at his disposal for field tests were ineffective and not adapted for work of a critical character and also to the contrary that with these instruments we were able to detect errors of plotting as small as the 1-200th part of an inch. He has yet to prove that the graphical errors, which he asserts exist, were not largely of his own making, with one or two exceptions of evident mistakes—and he has not hesitated to assert without positive proof that these graphical errors were due to errors in location measurements of from 1 to 14 ft., and to carry his point has had the assurance to contradict the accuracy of my statements regarding the records of the office.

He asserts that upon the scale of 1-600 or 50 ft. to an inch, 2-10th of a ft. is discernible, or the 1-250th part of an inch, and 1 ft. on a scale of 1-2,400th, or the 1-200th part of an inch. This is not logical, and his argument is hypercritical. I leave it to your readers to decide what is an open question. Taking into account the processes required in drawing a topographical map from field notes, how close can a map be relied upon for scale measure-

ments, allowing a reasonable amount of error to occur in every operation of plotting? Or, in other words, what is the accuracy of the location of a dot?

The errors due to the shrinkage of paper or the effect of the atmosphere, as well as those due to distortion in printing, far outweigh any errors made by the draftsmen in plotting maps. Yours very truly,

Josiah Pierce, Jr.,
Assoc. M. Inst. C. E.

921 Equitable Building, Baltimore, Md., Nov. 23, 1896.

(We have commented upon this letter upon our editorial page.—Ed.)

Economy of Gas Engines using Gas made from Anthracite Culm.

Sir: I have received a marked copy of your issue of Nov. 12 calling my attention to a garbled extract from a paper recently read by me before the Scranton Board of Trade. The slur you cast at "the inventor" would deter me from giving the article any attention were it not for the request of the Secretary of the Board of Trade by whose solicitation the paper was prepared and read. Aside from some verbal corrections a portion of the extract should be corrected to read, "By actual measurement we produce and store from 118,000 cu. ft. to 120,000 cu. ft. of gas with one ton of fine waste from the washery." The "230 HP." you recognize as probably a misprint for 280."

Your assertion that "it would be interesting to know what kind of gas it is that can be obtained from anthracite culm in such large volume as 140,000 cu. ft. per ton" shows great lack of knowledge for a critic. The chemical analysis as made at the laboratory of the Lackawanna Iron and Steel Co. is:

C. O_2	3.80	C. H_4	0.66
O.	0.40	N.	46.49
C. O.	28.80		
H.	19.85		100.00

I should get about 170,000 cu. ft. of this gas from 2,000 pounds of coal. Notwithstanding many leaks, after washing and cooling I collect in the holder about 140,000 cu. ft. You can verify this by sending an agent to investigate—but, perhaps, if you will consult authorities on this subject you may think is unnecessary.

Mr. H. L. Gantt in "Cassier's Magazine," Nov., 1895, p. 48, tables 2, 3 and 4, give volume of anthracite gas from steam blown producer per 100 lbs. coal, varying from 7,580.15 cu. ft. to 8,114.0 cu. ft.

Mr. W. J. Taylor gives about 170,000 cu. ft. per ton of coal as his experience.

Now as to the allowance of 50 cu. ft. of gas per HP. per hour. There are responsible gas engine builders, who guarantee their engines not to consume more than 17 cu. ft. illuminating gas per HP. per hour. By reference to a long list of tests given in "tables of trials and tests of French and German gas engines, using lighting gas, 1885 to 1895," by Bryan Donkin, London, I find the consumption of gas, including ignition per brake HP. to be from 14.20 cu. ft. to 45 cu. ft. in different engines; 20 cu. ft. per HP. per hour being a fair allowance for average illuminating gas, and eliminating the 46% nitrogen as an inert quantity, in our producer gas, it would seem as if 50 cu. ft. per HP. per hour was a liberal allowance.

Now as to the quantity of culm consumed per HP. per hour. Culm is very pure carbon, the finer it is the freer of slate, and the gas we produce with it is higher in C. O. and H. and lower in N. than that from prepared coal.

The "Dowson gas" has become celebrated in Europe as a cheap power and fuel gas. It is made with anthracite coal or coke, and contains about 55% N. By reference to the table of "Trials and tests of gas engines, using power gas, 1881 to 1895, English, French and German," given by Mr. Donkin, I find that coal consumed per I. HP. per hour was from 0.76 lbs. to 1.45 lbs., and per B. HP. per hour was from 1.02 lbs. to 1.97 lbs. In test made by Prof. H. W. Spangler, of the University of Pennsylvania, and quoted by Mr. Gantt in the article before referred to, the results are stated as follows, viz.:

Coal used per I. HP. per hour	= 0.9511 lbs.
Coal used per B. HP. per hour	= 1.315 "
Combustible per I. HP. per hour	= 0.8302 "
Combustible per B. HP. per hour	= 1.148 "

The engine was the Otto and the gas analyzed as follows, viz.:

C. O.	25.38	C. O_2	4.02
H.	4.51	N.	64.04
C. H_4	1.79		
O.	0.26		100.00

If you will compare this with the gas we are producing from culm you will not find my statements so very extravagant in the light of what has been before accomplished. In fact I expect to do considerably better, and if you will study up what has been accomplished in this line, you may be less sarcastic in your reference to the "inventor."

I remain, very respectfully,

J. Gardner Sanderson, C. E.,
M. Am. Soc. C. E.

Anthracite Gas Producer Co., Scranton, Pa.,
Nov. 18, 1896.

(Answering the first paragraph of our correspondent's letter, we would disclaim any intention to "cast a slur" at the inventor. It is our constant endeavor in the preparation for publication of notes concerning new inventions, etc., to point out briefly those features in which claims made seem to most need checking and verification. The "garbling" to which reference is made was not done by us. We reprinted the extract as we found it in the Scranton newspapers.

Taking up now the questions raised, it appears from Mr. Sanderson's letter that he makes even a larger claim than we supposed. We computed that he claimed a fuel economy of 0.8 lb. of culm per HP.-hour, on the basis that he allowed 2,240 lbs. to a ton. It appears from his letter above, however, that he referred to a ton of 2,000 lbs. in his estimate of a gas production of 140,000 cu. ft. per ton of culm. Hence we have 140,000 cu. ft. ÷ 50 = 2,800 HP.-hours. Then 2,000 lbs. ÷ 2,800 = 0.714 lbs. of culm per HP. per hour. If Mr. Sanderson were to reach a product of 170,000 cu. ft. of gas, as he says he ought to do, this remarkable efficiency would be still further reduced, and would become only 0.588 lbs. per HP.-hour.

We must still refuse to believe that so economical a figure for power generation by gas engines is feasible until it is verified by actual tests. The best results obtained by Prof. Spangler, which are cited above, were 0.951 lbs. of fuel per I. HP. The 0.714 lbs. claimed by Mr. Sanderson is 25% better than this.

It seems highly probable that the point in which Mr. Sanderson's estimates are defective is his assumption of 50 cu. ft. of his gas as sufficient for a horse-power hour. He calls this "a liberal allowance." We do not think it is at all liberal. Accepting this analysis of the gas given in his letter, although it is surprisingly high in hydrogen, we have computed its heating value per cubic foot, and find it to be 41.72 calories (=165.6 British thermal units), using the figures given in Butterfield's "Gas Manufacture" for the heating value of the constituent gases. Butterfield gives 37 calories for the heating power of Dowson gas, and 155 calories for London illuminating gas. The average heating value of New York city illuminating gas is 710 heat units (= 179 calories), according to Dr. E. G. Love. The average of these two figures for illuminating gas is 167 calories, or just four times that of Mr. Sanderson's gas. The consumption of illuminating gas per I. HP. being 20 cu. ft., which Mr. Sanderson says is a fair allowance, it would be reasonable, in the absence of direct evidence to the contrary, to say that the consumption of a gas of only one-fourth the heating value would be four times as great or 80 cu. ft., instead of 50 cu. ft., as he assumes. This would raise the consumption of culm per I. HP.-hour from 0.714 to 1.14 lbs. which we should consider reasonable.

Again, taking the above figures of 165.6 B. T. U., as the calorific value per cu. ft. of Mr. Sanderson's gas, we find that 50 cu. ft. would contain 8,280 B. T. U. In the table in Donkin's work of efficiencies of gas engines worked with illuminating gas, to which Mr. Sanderson refers, the British thermal units per I. HP. developed are given for each test, and the average is, we should judge, about 13,000 B. T. U. Still, again, the same authority gives the consumption per I. HP. of Dowson gas as 90 to 100 cu. ft. and over, and its calorific value is not very dissimilar to that which we have computed for Mr. Sanderson's gas.

It will be a surprise to most of our readers to learn that "culm is very pure carbon—the finer it is the freer from slate." We have always supposed the reverse. The late Eckley B. Coxe (Trans. Am. Inst. Mining Engrs., Vol. XIII., p. 706), gave the following percentages of ash in different sizes of anthracite coal shipped from one mine: Egg, 5.66; stove, 10.17, chestnut, 12.67; pea, 14.66; buckwheat, 16.62. In the article on Utilization of Anthracite Culm, published in our issue of Dec. 26, 1895, we gave the value of No. 1 culm as 78% and No. 2 as 70% of the value of egg coal, on the authority of Mr. Wm. McClave, of Scranton. The culm is apt to contain a greater quantity of moisture than the screened sizes and also a greater quantity of dirt. Further, if we are not misinformed, in the culm piles generally the pieces of slate from the breakers are mixed with the fine refuse.—Ed.)

Notes and Queries.

C. H., Macomb, Ill., asks, "What is the angle or grade of repose of an ordinary four-wheeled wagon on a brick pavement?" It would doubtless vary within wide limits with the condition of the surface as respects mud, dust, smoothness, etc. If any of our readers have made any tests, however, we shall be pleased to print their results.

HIGH BUILDINGS AND SAFE ELEVATORS.

We have received from a number of the principal makers of elevators, letters discussing the questions raised by the editorial in our last issue, and present herewith such portions of them as are of general interest.

Mr. L. S. Graves, President of the Graves Elevator Co., of Rochester, N. Y., presents what to us is an entirely new reason for limiting the height of buildings in proportion to the width of the streets on which they are built, as follows:

You speak of the economical value of high buildings, which is probably true, but as a citizen I should say there was another very serious side to this question. If there is no legal limit to the height of buildings in New York or other large cities, how will Broadway (for instance) and the other streets of New York look in 50 or 100 years from now, lined on both sides with buildings twice as high as the width of the streets? But a more serious question is, how will the streets and sidewalks, and transportation facilities take care of the greatly increased number of people which can be accommodated for business and office uses in those high buildings, crowded as they are now, and no chance to increase their capacity. It seems to me curious that the papers have not taken up and discussed this subject before.

I think the heights of buildings should be regulated by the width of streets. London and Paris, as you say, seldom have buildings more than five stories in height, and very few elevators to my knowledge. The tendency in this country is for buildings from 15 to 24 stories in height, but with our elevators and our Americanism, perhaps we could afford to double the height of buildings in the old country. A happy medium, it seems to me, would be from ten to twelve stories high.

With our extremely high buildings, 700 ft. per minute for elevators may not be too high a speed for economy and convenience, but if buildings were limited to 12 stories and the speed of elevators limited to 500 ft. per minute, I think we should be in a much more sensible condition as to the question of safety and the future condition of streets and sidewalks.

The need of broad and unobstructed sidewalks, in an office building district, is already apparent, both in New York and Chicago, and we believe to some degree in the narrow streets of Boston and Philadelphia as well. The great trouble, however, is that the present sidewalks are constantly obstructed. The solution of the problem may, perhaps, be found in adding stories to the sidewalks as well as to the buildings.

A prominent New England elevator manufacturer sends the following discussion respecting elevator safety devices:

We have read with great interest your article on safe elevators and high buildings, and believe you have reviewed the subject very thoroughly.

There is one suggestion in your article that we think you lay too much stress upon; that is, that every elevator should be furnished with a brake under the control of the operator to suspend the car from the safety devices at every landing. There may be instances in which such an arrangement would be the cause of very serious trouble; especially on elevators where the motive power was other than hydraulic. Suppose a car to be suspended in this way in the downward trip, and for some reason the mechanism would keep on running, there would be nothing to indicate this to the operator in the car, and as he would be obliged to release his safeties before applying his power, the result would be that the moment the safeties were released the car would drop. We might cite several circumstances under which this same difficulty would arise.

We note you refer to the infrequency with which safety appliances are inspected, and on this you touch a vital point. Few safety devices on elevator cars are inspected regularly, and a safety which is not kept in free working order is worse than no safety at all.

Another point which we think you might emphasize is the tendency in elevator construction to increase the amount of mechanism between the operator in the car and the controlling valve of the hydraulic machine. We have, as you know, lever devices, wheels in the cars, and

even electric buttons, and in each of these cases the mechanism between the operator and hydraulic valve is quite intricate. The simple method of passing a wire cable from the valve, passing directly through the car, and in control of the operator, removes many opportunities for breakages or disarrangement of fine mechanical parts.

Another source of danger which you have failed to touch, and which has caused many accidents, especially on the direct plunger type of elevators, arises in this way: The elevator is built to raise a maximum load of say 2,000 lbs.; on special occasions the elevator may be loaded beyond this point, with the result that the car will fail to ascend, the load in the car overbalancing the pressure on the hydraulic piston. Before ascertaining that the car is overloaded the operator has been obliged to open his hydraulic valve, and quite often will start to lighten his load by asking his passengers to step out of the car without reversing the valve; but as soon as the load comes below the maximum the car will immediately start, and a number of people have been killed by being caught in the act of stepping from the car.

We may best answer the objection raised above by explaining more in detail our suggestion for the safety attachments of an elevator car as follows:

Let safety clutches be arranged to automatically grip the guides either when the elevator reaches a certain speed, or when the rope supporting the car breaks or is slackened. Let either these safety clutches or a separate and independent pair of safety clutches be placed under control of the operator and so interlocked with his operating lever and with the gates, that he must apply these clutches whenever he brings his elevator to a stop before he can let off passengers, and must release them before he can move his operating lever from the stop position.

Now, suppose that at some stop the machinery goes on moving while the elevator car stands at the floor. If the car were on its way down, the suspending rope would slacken. This would at once lock the safety clutches, and the operator, if he attempted to start the car down, would find it impossible to do so, for the safety clutches would be held fast by the slackening of the suspending rope.

On the other hand, suppose the car is on its way up. It stops at a floor, and while it stands there by some accident the machinery starts up again; but the operator's safety clutches being locked fast the machine is stalled, and the car cannot start until the passengers are on and the operator releases the safety clutches.

It may be remarked here that the most fruitful cause of accidents in connection with elevators is not failure or defects of the apparatus by any means, but carelessness on the part of the operators. There is a constant tendency to hurry-up things in the average office building elevator service, and there is always a certain amount of risk that a green or nervous operator will start his car a little too soon and catch a passenger in the door.

Every owner of a building in which an elevator is operated is liable to damage suits from accidents of this sort, and every elevator manufacturer has to subject his reputation to a certain extent to risks of this class. The value of a mechanical check to prevent such accidents ought to be clear.

We may note that the very class of accidents referred to in the last paragraph of the letter above would be prevented by the apparatus we have suggested. An operator with an overloaded car would be obliged to move his lever to the stop position and apply his safety clutches before he could open the gate to let passengers off.

The Crane Elevator Co. of Chicago writes us as follows:

Agreeing with you thoroughly as to the comfort, convenience and business necessity of the high office building, we may as well also agree that that type of building has come to stay. It would seem to us, from what we have heard of it, that this accident at the American Tract Society Building occurred primarily from there not being a sufficiently large factor of safety in that part of the elevator equipment which gave way. What should and must be thoroughly understood by elevator builders is that it is far more necessary to exceed in strength in every part of the elevator plant than by safety devices to guard against possible weaknesses. While it is true that the latter duty should be deeply and thoroughly considered, still that is secondary to the first duty of providing a very large factor of safety. First, decide what that factor of safety will be, erring if anything on the side of extreme precaution, then make the most thorough and rigid tests of the entire plant, in position, to such an extent as will be far beyond anything that we know it is possible to put upon the plant in actual service. After this is done every means may be considered of avoiding unforeseen accidents or latent defects which have not shown up in tests.

While the height of a building has nothing to do with the safety of its elevator, yet it must always be borne in mind that the farther you fall the harder you hit, and that in extremely high buildings the requirements of the elevator service are much more exacting than in the ordinary six to ten-story building. In providing against all possible weakness in elevator service, the same rule prevails as in all other lines of manufacturing business, namely, that long experience is an absolute necessity for arriving at the best results. This is emphasized strongly by the very accident that has called forth your editorial. In this case a manufacturer of long experience, admirable equipment, engineering talent, and every facility for giving first-class work, is yet confronted with an accident which evidently had not been provided against. In considering the matter of safety in elevators, it must be remembered that accidents involving the risk of loss of life or actual injury to passengers are extremely rare on first-class elevators, when the enormous travel in this line is taken into consideration; indeed, it is probable that a hundred times more people are killed by falling down stairs than by falling with elevators, and the scarcity of such accidents cannot but reflect credit on those manufacturers who have for so many years supplied the public with this class of machinery.

We agree with you that the statement that the cause of the accident at the American Tract Society was the high pressure upon the system, is not correct. A high pressure, such as was sustained at this building (about 900 lbs.) is as perfectly safe as the ordinary pressure of say 125 lbs. All that is requisite is that the proper factor of safety should enter into every detail of the construction of the plant, and then there is not one particle more danger in the 900 lbs. pressure than there is in the 125 lbs. We think you are correct in ascribing the cause of such an accident as the one under discussion largely to the severe requirements as regards speed which are now imposed upon elevator builders, by architects and owners of these high office buildings. We think you are in error, however, in one or two points on this particular subject. A speed, such as that you mention, of 700 ft. per minute, is not absolutely requisite for first-class elevator service in office buildings even of 16 to 25 stories, except on elevators which are used as "express" elevators; that is to say, running from the first to the eighth or tenth story without stop. During this through run the speed of 700 ft. per minute, or even more, may be desirable or may be attained without any inconvenience or risk; but when stops are made at every floor, say every 12 ft. or so, a speed exceeding 500 ft. per minute is unnecessary, undesirable, and practically impossible; that is to say, if between the throwing a lever on the "up" and the centering of that lever for a "stop" a speed of 700 ft. per minute had been attained in 12 ft., the stop cannot be nearly as good as if the speed were only 500 ft. per minute, and consequently the results, so far as time is concerned, are not as good as if the lower rate of speed were adhered to.

As regards safeties, few or none of the modern elevator builders construct an elevator without an automatic safety device which is intended to be thrown in when the car attains an excessive speed. The trouble, as you rightly say, is that elevator builders are now required to construct their work so that the cars will come down, even with light loads, at such a high rate of speed that the safeties must be set to throw in at such a rate of travel that passengers may be injured by the descent of a car less quickly than the figure at which the safeties are set to act. At 200 ft. normal speed the safeties will generally be set to throw in at about 400 ft. per minute, and at 500 ft. normal speed at about 800 ft. per minute. It can readily be seen then that in the case of such an accident as has happened at the Tract Society Building, if the normal speed were 500 ft. the car might come down at a speed of 700 ft. per minute without throwing the safeties, although we know that the landing of the passengers at the bottom of the shaft at such a rate of speed as this involves an absolutely serious risk. There is no good reason, as you say, why a device should not be put in the elevator car which would enable the operator to throw the safeties in and hold the car at any point in the hatchway. It must be remembered, however, that such a device would only be good if the operator preserved his coolness and presence of mind, still it is a step in the right direction, and will undoubtedly be used in connection with the high speed elevators which have necessitated it. Another element of safety which should always be present, is that every elevator plant should be in charge of a first-class engineer thoroughly competent and versed in the proper methods of caring for elevator machinery. Too often owners of buildings seem to think that elevator machinery and its care needs no skilful attention, and they are willing to entrust one of the most vital points of their building, and one on which the lives of their tenants and others are trusted every day, to the care of a man who has not the capacity or experience necessary for such a task.

In conclusion, we can but reiterate that the main elements in a safe elevator service are:

First, a very large factor of safety. Second, the testing of all the machinery in place rigorously and carefully. Third, the providing of every approved device against unforeseen accidents; and lastly, a most intelligent and careful maintenance of the entire plant in every particular.

In our last week's issue we referred to the fall of an elevator in the Manufactures Building at Chicago in 1893. Fuller details of this accident are sent us by a correspondent as follows:

Sir: In your issue of Nov. 26 you mention the accident which happened to one of the elevators in the Manufactures Building at the Columbian Exposition. As I happened to see the car drop, I will give an account of it.

The accident happened on the night of Oct. 21, 1893, to one of a group of four electric elevators (not hydraulic elevators, as you say). Without any warning, one of the outside cars, which had just started to go down, filled with passengers, began to drop with a series of lurches in its descent, and was finally stopped by becoming jammed between the guide posts, about 60 ft. from the ground. The outside guide post was a stick of timber about 12 ins. square, which was forced out of line by the automatic clutches under the car. This allowed the car to list to one side and become jammed between the guides. The timber broke when the car came to a stop. Fortunately, it did not give way entirely, but held the car in its distorted position until a fire company brought ladders and released the passengers from their perilous position. If the guide post had broken, so as to allow the car to drop entirely out of its guides, every one in the car would have been killed. The lesson is a valuable one, as the lack of rigidity in the guide posts is a defect which can be seen in some of our modern elevators.

Yours truly,

J. W. Schaub, M. Am. Soc. C. E.,
Chief Engineer and Manager Hamilton Bridge Works.
Hamilton, Canada, Nov. 30, 1896.

Besides the above correspondence, several elevator builders have favored us with their opinions in personal interviews. One of these gentlemen makes some interesting comments upon the city inspection of elevators. He says that this official inspection is, as a rule, either a farce or a piece of blackmail. The inspectors are not expert elevator mechanics, and as a result their investigation is superficial and of no account. The "defects" which they find are, as a rule, not real defects at all; but are either trivial things of no importance, or else they condemn parts of the machinery which are actually in perfect condition. The cases taken to court are, in practically every case, instances where the long-suffering owner refuses to submit to downright imposition or blackmail, and prefers to fight the case in court. It will be readily understood that most owners will prefer to submit to a good deal of loss rather than go to law, for the mere fact that fault had been found with an elevator, justly or unjustly, which is made public by an action at law, would be sufficient to prejudice tenants against a building.

On the other hand the systematic inspection of elevators which is made by elevator builders and by companies insuring against elevator accidents, is exceedingly valuable. These companies employ elevator constructors of thorough experience, and as they have a financial interest at stake, careful and intelligent work is assured.

It will be remembered that in our editorial last week, we ourselves pointed out that to rely on a municipal inspection for safety was leaning on a broken reed. The above opinions lend additional force to what we then said. Whether the charges made are true or not, it is clear enough that under political conditions which may at any time obtain in any city, they may become true. It may indeed be that a certain amount of municipal inspection is a necessity to check dangers in the cheapest class of buildings, where a cheap elevator is put in charge of a cheap engineer and is left to take care of itself; but as we recently said with respect to municipal building inspection, we hold it to be a mistake to so greatly magnify this work, that owners and builders will begin to rely on such inspection instead of on the watchfulness of their own architects and engineers for good and safe construction.

METHOD OF DETERMINING THE WORK DONE DAILY BY A REFRIGERATING PLANT AND ITS COST.*

By Francis H. Boyer, M. Am. Soc. M. E.**

The refrigerating plant in the Abattoir of John P Squire & Co., East Cambridge, Mass., was installed by the De La Vergne Refrigerating Machine Co., during the winter and spring of 1890 and 1891. It is composed of two machines rated by the builders as 150 tons ice-melting capacity each daily or a combined capacity of 300 tons, this to be accomplished by running 24 hours daily with a return pressure of 26 lbs. above atmosphere, a condition of 40.7 lbs. pressure absolute, running at 40 revs. per minute. The size of the gas compressing cylinders were 16 ins. in diameter and 32 ins. stroke, being double acting, four gas cylinders all told.

The condition and amount of work being done is indicated by the back or return pressure of the gas—this contendant reduces the supply. This first makes its appearance from 7 to 9 o'clock p. m., and at 10 p. m. the volume of return pressure of gas has become so low that the attendant has slowed down the machines from 45 to 36 revs. per minute, and at this condition the work is kept up until 7 a. m. the following morning. At 2 a. m. there is an increase of a return pressure, which continues until 7 a. m.; this is caused by a gang of about 100 workmen beginning at 1 a. m.

A little story is told in the Water Condenser column in the initial column marked "I."

At 7.00 a. m.	the temperature	was	....	67 degrees.
" 1.00 p. m.	"	"	....	73 "
" 8.00 p. m.	"	"	....	67 "
" 2.00 a. m.	"	"	....	70 "
" 6.00 a. m.	"	"	....	67 "

This is due to the condition of the tides, the coldest water coming at high water and warm at low water. Here we find that our thermometer gives us a correct reading

ENGINEER'S DAILY REPORT.

JOHN P. SQUIRE & Co. CORP., East Cambridge, Mass. Department 24. Date, *July* 18, 1896.

	Engine Room. D. P.	R. P.	Revolutions. No. 1.	No. 2.	No. 3.	No. 4.	Salt Water Column.	Steam.	Vacuum.	Refrigerator Temperatures. 1	2	3	Ham Room.	4	Rib Room.	Hanging Room. 1	2	3	4	6	7	Steam Lard.	Leaf Lard.	Oil Room.	Oil Cellar.	Beef House. 1	2	3	4	Water Condenser. I	C.	F.	Weather. Temp.	Conditions.	Remarks.
7 A.M.	165	13	45	45	..	..	110	80	24½	41	41	41	33	39	33	38	36	33	33	42	38	51	47	"	42	39	35	33	33	67	76	102	68	Clear	Turn gas on water tank 8 A.M.—*G. M. D.*
8 "	170	13	45	45	..	..	100	80	24	..	..	..	..	..	..	39	36	34	33	..	..	..	..	..	..	..	..	..	..	67	77	105	70	.....	
9 "	170	13	45	45	..	..	100	80	24	42	42	41	33	40	38	39	36	35	33	43	38	53	49	..	43	40	35	35	33	67	77	108	70	.....	
10 "	170	14	45	45	..	..	100	80	24	..	..	..	..	..	..	39	36	36	33	..	..	..	..	..	..	..	..	..	..	67	77	116	68	.....	Keep ham room normal.—*J. Crowley.*
11 "	180	14	45	45	..	..	95	75	24	..	..	..	..	..	..	40	36	36	34	..	..	..	..	..	..	..	..	..	..	71	77	115	78	.....	
12 "	180	15	45	45	..	80	95	80	23¾	42	42	41	35	40	35	42	37	36	35	43	38	54	49	..	43	38	35	35	33	72	77	115	76	.....	No. 3 room closed blower on
1 P.M.	180	15	45	45	..	..	95	80	23	..	..	..	..	..	..	42	37	36	35	..	..	..	..	..	..	..	..	..	..	73	77	114	75	.....	temperature 48 degrees.
2 "	180	15	45	45	..	..	95	80	24	..	..	..	..	..	..	42	37	36	35	..	..	..	..	..	..	..	..	..	..	71	78	114	75	.....	Fire alarm test O. K. 8.30 A.M.
3 "	180	15	45	45	..	..	95	80	24	42	42	41	36	40	37	42	37	36	36	43	38	54	49	..	43	36	34	34	33	72	79	117	73	.....	" " " " 12 noon.
4 "	180	14	45	45	..	..	95	80	24	..	..	..	..	..	..	40	37	36	36	..	..	..	..	..	..	..	..	..	..	70	81	121	72	.....	Fire box 21 Somerville alarm
5 "	175	13	45	45	..	..	95	80	24	..	..	..	..	..	..	40	36	36	36	..	..	..	..	..	..	..	..	..	..	68	80	115	72	.....	8.30 A.M., and out 8.45 A.M.
6 "	175	13	45	45	..	..	95	80	24½	42	42	42	34	40	36	39	36	35	36	43	38	55	51	..	44	36	34	34	34	67	78	112	72	.....	(Signed) JAMES HIGGINS, *Engineer.*
7 "	170	12	45	45	..	..	100	80	25	..	..	..	..	..	..	39	36	36	37	..	..	..	..	..	..	..	..	..	..	67	78	113	71	.....	
8 "	165	11	45	45	..	80	100	80	25	..	..	..	..	..	..	39	36	36	37	..	..	..	..	..	..	..	..	..	..	67	78	114	69	.....	Start both coils in rib room
9 "	165	10	45	45	..	80	95	80	25	..	..	..	..	..	..	39	36	36	37	..	..	..	..	..	..	..	..	..	..	67	78	115	68	.....	Sunday 12 P.M.—*W. Lincoln.*
10 "	165	10	36	36	..	80	95	80	25	41	41	42	34	40	36	38	36	36	37	42	38	54	50	..	43	34	34	33	33	67	78	114	67	.....	
11 "	165	10	36	36	..	80	95	80	25	..	..	..	..	..	..	38	35	35	36	..	..	..	..	..	..	..	..	..	..	68	78	115	66	.....	
12 "	170	9	36	36	..	80	95	80	25	..	..	..	..	..	..	38	35	35	36	..	..	..	..	..	..	..	..	..	..	69	79	114	65	.....	
1 A.M.	170	9	36	36	..	80	95	80	25	..	..	..	..	..	..	37	35	35	36	..	..	..	..	..	..	..	..	..	..	70	79	113	64	.....	
2 "	170	11	36	36	..	80	95	80	25	42	42	42	34	40	36	37	35	35	35	42	38	50	46	..	43	34	32	32	32	70	80	118	62	.....	
3 "	170	12	36	36	..	80	95	80	25	..	..	..	..	..	..	36	34	34	34	..	..	..	..	..	..	..	..	..	..	70	80	117	61	.....	
4 "	165	12	36	36	..	80	90	80	25	..	..	..	..	..	..	36	34	34	34	..	..	..	..	..	..	..	..	..	..	69	79	116	60	.....	
5 "	165	13	36	36	..	80	90	80	25	..	..	..	..	..	..	36	34	34	34	..	..	..	..	..	..	..	..	..	..	69	78	117	59	.....	
6 "	165	13	36	36	..	..	95	80	25	..	..	..	..	..	..	35	34	34	34	..	..	..	..	..	..	..	..	..	..	68	78	116	63	.....	(Signed) PAT FOLEY, *Engineer.*

Engines Hours Run.				Boilers Hours Run.				Coal Receipts.	Daily Tons Refrigeration.	Salt Water Counter.		Gallons to date.
No. 1.	27,339	24	27,363	No. 1.	25,778		25,778	Pocahontas.	$\frac{48}{24} \times \frac{40.5}{40} \times \frac{12.4}{26} \times \frac{150}{1} = 145.5$ tons.	No. 1.	603,484	1,357,600 to-day.
" 2.	27,935	24	27,959	" 2.	21,739	24	21,763	9,110 pounds.		" 2.	287,642	964,200 "
" 3.				" 3.	21,644	24	21,668	9,480 "				2,321,900 "
" 4.	9,593	10	9,603	" 4.	21,309		21,309	9,500 "				32,634,300 to date for July.
" 5.	1,068		1,068	" 5.	24,024	24	24,048	8,490 "				34,956,300 total for 18 days in July.
				" 6.	22,542	24	22,542					
				" 7.	16,644	24	16,648	36,980 pounds.				
				" 8.	23,323		23,323					

"P. D." indicates direct pressure or pressure at which the ammonia gas is being liquefied.

"R. P." indicates return or suction pressure—all pressures starting at atmosphere.

Engines Nos. 1 and 2 are refrigerating engines. Engine No. 4 is a 200 HP. electric light engine. Engine No. 5 is an air compressor for testing car-brakes.

"Salt-water column" is expressed in feet of hydrostatic pressure. It is pumped 1,800 ft. through a 12-in. cast-iron pipe, steam being conducted under the ground. Water is taken from the bay, and is therefore salt water. The water is first used to condense ammonia, and finally to condense the steam in a Wheeler 1,000 HP. surface condenser.

In "Water Condenser" columns, "I" is initial temperature to ammonia condensers; "C" is temperature of water on entering steam condenser; "F" is final temperature of water leaving steam condenser.

"Engine Hours run" indicate the number of hours the engine has run from the time they started. This I find quite an important item as engine drivers are apt to become prejudiced against one or the other engine where one engine remains idle, as it does in this case during the cold winter days.

"Remarks" come in shape of instructions from Department Superintendents—test and fire alarms.

dition being maintained by the speed of the gas pump—the engines being directly connected and constructed to allow of a variation of speed from 15 to 75 or more revs. per minute.

It became desirable to establish a method to obtain the amount of work accomplished daily in order to arrive at the expense of operation, and to make comparison with results of other departments of the abattoir. By taking the cubic displacement of the compressors with a given amount of return pressure the amount was obtained easily.

The accompanying table is a copy of the Engineer's log for July 18, 1896:

The engine had run from 7 a. m. to 10 p. m. at 45 revs. per minute, during which time between 2,000 and 3,000 hogs had been slaughtered and placed in the "hanging-rooms" for cooling, which has a floor space of about one acre, or to be exact 42,240 sq. ft. Rooms No. 1-2-3-4-6 and 7 have the same floor area. The temperature of the hanging-room increased from 38° to 33° at 7 a. m. to 42°—36° F. at 2 p. m. At this time the most severe work was being done by the machinery. This is shown by the return pressure of the gas being at 15 lbs., and the direct pressure at 180 lbs. per sq. in. As the temperature in the hanging-room decreases so does the work on the engines. Reference will be made only to the hanging-room, as there is where most of the work comes from. Rooms No. 1-2-3-4-6 and 7 are used for curing and storage purposes, and work coming from there comes from heat radiating from workmen, from lights, from decomposition in process of curing, and from imperfect insulation. From the last source there is but little trouble as the building has few windows, no hallway or elevators, no communication between floors, and brick walls 48 ins. thick.

As the coils circulating the ammonia becomes cold, and the unexpanded liquid returns to the engine, the attendant reduces the supply. This first makes its appearance from 7 to 9 o'clock p. m., and at 10 p. m. the volume of return pressure of gas has become so low that the attendant has slowed down the machines from 45 to 36 revs. per minute, and at this condition the work is kept up until 7 a. m. the following morning. At 2 a. m. there is an increase of a return pressure, which continues until 7 a. m.; this is caused by a gang of about 100 workmen beginning at 1 a. m.

of conditions of the tides, clearly defining high and low water.

The object of this paper, which is to ascertain the amount of work done daily under these varying conditions under the heading of "Daily Tons of Refrigeration" is the following:

$$\frac{48}{24} \times \frac{40.6}{40} \times \frac{12.4}{26} \times \frac{150}{1} = 145.2 \text{ tons,}$$

$\frac{48}{24}$ being the number of hours which the engines have done service.

40.6 is the average number of revolutions for the day, 40 being a fixed number of revolutions necessary to establish a given result of effort.

12.4 is the average return pressure of the gas from the refrigerator.

Twenty-six lbs. per sq. in. is the fixed pressure for a given result, 150 being the rated capacity of the machines when the fixed conditions are maintained, or we should have as a fixed formula:

Hours.		Revolutions.		Return Pressure.		Tons Refrigerating. 150
24	×	40	×	26	×	1

Average varying being daily entered.

To prove the statement is an easy matter by taking the weight of the condensing water from the ammonia condensers, also the oil cooler, and multiplying by the heat units will establish the amount of heat being given. I will not attempt to go into detail, as this is already on record in the Society Transactions, in the able paper on "Refrigerating Machinery," by Professor Denton, Vol. X., p. 792.

In determining the cost of operating, several tests had been made on the boiler and engine plant, which showed an average of 10.4 lbs. of water vaporized per pound of coal consumed, Pocahontas coal from Virginia being used, and with an efficiency of 16.44 lbs. of steam per hour per HP., or 1.56 lbs. of coal per hour per HP. From this data is established the amount to be charged to electric light and car department for the air compressor for testing air-brakes.

The total amount of expense for operating is taken monthly from the store-room accounts; from the year 1894 we have the following:

Tons of refrigerating produced....	48,466½
Cost of maintaining refrigerating department, including annual repairs	$28,471.03
Average cost per ton for refrigeration for 1894.	58.7 cts.

An interesting feature of the monthly production and cost per ton of refrigerating is shown as follows:

1894.	Tons.	Cost per ton.
January	1,816	85 cents.
February	1,423	86 "
March	1,538.3	33 "
April	2,821.7	73 "
May	4,747.3	46 "
June	5,491.7	38 "
July	6,736.4	31 "
August	7,596.6	27 "
September	6,283.4	24 "
October	5,419.5	52 "
November	2,647.5	78 "
December	1,945.1	82 "

*A paper presented at the New York meeting of the American Society of Mechanical Engineers.

**Chief Engineer, John P. Squire & Co., East Cambridge, Mass.

ANNUAL MEETING OF THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

The annual meeting of the American Society of Mechanical Engineers, which is being held at its house in New York city this week, promises to be the largest meeting ever held by the society. Over 300 members and guests were registered before the close of the first session on Tuesday evening, and the list was enlarged by Wednesday noon to 394. One of the features of the meetings of this society, which contributes largely to facilitating the making of acquaintances, is the wearing by each member and guest of a badge with a number in figures, which may easily be read a few feet distant, and the printing once or twice a day of the complete members registered with the badge number adjacent to each name. This system is especially valuable to those who have an imperfect memory of names and faces.

The opening session on Tuesday evening consisted first of an informal gathering of the members and guests, among whom were many ladies, in the rooms, both up and down stairs, which lasted till 9 p. m., when those who could find seating or standing room crowded into the auditorium to listen to the address of the retiring president, Mr. John Fritz. We postpone the publication of this to our next issue.

It is not the usual custom to discuss the address of the president, but Lieut. W. H. Jacques, U. S. N., who is a member of the society, made a brief response, in which he told something of the history of the beginning of armor plate and heavy gun forgings in this country, and of the work of the Naval Advisory Board of which he was a member, which led to the starting of the new manufacture at the Bethlehem Steel Works. He was followed by Mr. Andrew Carnegie, who, in a most happy speech, paid tribute to Mr. Fritz and to the other metallurgical and mechanical engineers who had done so much for the iron and steel industries. Historical reminiscences of the steel men being in order, Messrs. Robert W. Hunt and Robert Forsyth were called on to speak on behalf of the Bessemer steel manufacture, and Mr. Samuel T. Wellman on the open-hearth process. After the speechmaking, the informal reception was continued, and lasted till midnight.

On Wednesday morning, the session began with formal business, consisting of reading of the reports of the council, of the tellers of election, and of the chairmen of several committees.

The Report of the Council.

The report of the council opened with a tribute to the late Mr. J. F. Holloway, Past-President of the Society. The membership of the society is now 1,762, of which 104 are Associate Members, 300 Junior Members and 16 Honorary Members. The society has been officially represented upon the commission for revising the New York Building laws by Messrs. Henry R. Towne, C. W. Hunt and S. W. Baldwin. A delegate to the National Conference on Standard Electrical Rules was appointed in the person of Mr. C. J. H. Woodbury. The council presented a memorial to Congress respecting the position of the naval engineers; but refused a request that the influence of the society be excited in favor of the bills proposing the wholesale establishment of engineering experiment stations. The council has appointed Messrs. Coleman Sellers, John E. Sweet, Chas. T. Porter, Geo. M. Bond and Coleman Sellers, Jr., a committee to prepare material to be used in opposition to proposed Congressional legislation to make the metric system compulsory. Invitations were received from Nashville and Milwaukee, urging that those cities be selected for holding the spring meeting of 1897, but the council has practically fixed on Hartford, Conn., for this meeting. The tellers reported the result of the election of officers for the ensuing year as follows:

President, Worcester R. Warner, Cleveland; Vice-Presidents, Edwin S. Cramp, S. T. Wellman, W. F. Durfee; Treasurer, Wm. H. Wiley; Managers, H. S. Haines, G. C. Herring, A. W. Robinson. A letter from the secretary of the American Association of Steel Manufacturers was read, informing the society that the association had adopted the "Decimal Gage" for measuring materials. This is the system of measuring sizes such as thickness

of sheets and plates, and diameters of wires, rods, etc., in thousandths of an inch instead of by the ancient wire and sheet metal gages.

Reports of progress were read by the chairmen of committees on a standard method of testing boilers, and on standard methods of testing materials of construction. The business meeting being concluded, the presentation and discussion of professional papers was then begun. Under the admirable rules of the society all of these papers were printed and distributed in advance to those members who signified their intention to attend the meeting, so that those who wished had ample time to study them and prepare written discussions. The first paper was one by Sir Henry Bessemer, honorary member of the society, entitled "History and Technical Sketch of the Origin of the Bessemer Process." It was read in abstract by Prof. R. H. Thurston. This paper we present in full in this issue, and comment on it in our editorial columns. Mr. Wm. F. Durfee, who is the only surviving representative of the owners of the Kelly process patent of 1857, read a discussion of the paper in which he pointed out the relations of Kelly and Mushet to the Bessemer process. He was followed by Mr. Allan Stirling, who read an encomium upon Mr. Bessemer and upon the value of his services to the world. Mr. Robert W. Hunt and Mr. William Kent continued the discussion, both expressing their regrets that Mr. Bessemer had not seen fit to give due credit to the other inventors of the process which bears his name.

"Ancient Pompeiian Boilers" was the subject of the next paper. It was presented by Mr. W. T. Bonner, and illustrates and describes some bronze relics of Pompeii which are preserved in the National Museum at Naples. They are vessels for heating water, and show a remarkable analogy to the water-leg, water-grate, and water-tube boilers of to-day. The grate bars are tubes made from sheet bronze, rolled, and soldered or brazed. They open at both ends into the bottom of the water jacket, thus forming water-tubes through which traversed the water as it circulated in the boiler. "Method of Determining the Work Done Daily by a Refrigerating Plant and its Cost," by Francis H. Boyer, was the next paper. This paper we print in full in this issue. "The Promise and Potency of High Pressure Steam," by Prof. R. H. Thurston, of Cornell University, was then presented by its author. We shall print an abstract of the paper at an early date.

Wednesday afternoon was left free to the members, without any formal session. Invitations were received from many industrial establishments and other places of interest, and parties were formed for visiting these, while others of the members remained in the rooms and attended a meeting in honor of the memory of the late J. T. Holloway, past president of the society, at which addresses were made by some of his numerous friends.

The remainder of the report of the meeting will be given in next week's issue.

THE NEW ENGLISH MOTOR-CAR REGULATIONS.

The Local Government Board has issued to the County Councils and certain other local authorities of England and Wales, regulations with respect to the use of light locomotives on highways, their construction and the condition under which they can be used. These regulations went into effect on Nov. 14, 1896, and are practically as follows:

The expression "light locomotive," means a vehicle propelled by mechanical power, which is under 3 tons in weight unloaded, and it can only draw one other vehicle, with a weight for both not exceeding 4 tons, unloaded. The locomotive must be so built as not to emit smoke or visible vapor, except from temporary or accidental cause. The conditions imposed for a locomotive, exceeding 5 cwt. in weight, are that it shall be capable of traveling backward or forward; that it shall not exceed 6½ ft. in extreme width; that the tire shall be smooth, and 2½ ins. wide, up to 1 ton in weight of vehicle; 3 ins. wide for a locomotive weighing between 1 and 2 tons, and not less than 4 ins. for any weight exceeding 2 tons. In case a pneumatic or other soft and elastic tire is used, it may be rounded and provided with bosses or projections of the same soft material as is used in the tire. In this case the width of tire is measured when the tire is not under pressure.

The light locomotive must have two independent and efficient brakes; and the vehicle must be so constructed as to be always under control without causing undue interference with ordinary traffic. The weight of a light locomotive exceeding 1½ tons, and of a car hauled, must be conspicuously painted on such vehicles; the weight, not including that of the water, fuel or accumulators used. The name of the owner and the place of his abode or business must also be similarly displayed in letters not less than 1 in. high.

The person in charge must be competent to control and direct its movements, and lights must be lit between sunset and sunrise, with a red lamp in front and a white light in the rear. This latter regulation does not apply to any bicycle or trycicle provided for under the act of 1888. The maximum speed permitted is 12 miles per hour. If the light locomotive weighs between 1½ and 2 tons, the speed is limited to 8 miles per hour, and to 5 miles if the weight exceeds 2 tons. If any light locomotive is used on any highway to draw another vehicle the maximum speed is 6 miles per hour.

Various other minor regulations follow. The Secretary of the Local Government Board calls attention to the fact that light locomotives which are carriages or hackney carriages, under the definition of the Inland Revenue Act of 1888, must pay an additional excise duty at the following rate: £2 2s. if the weight exceeds 1 ton but is under 2 tons, unladen; and £3 3s. if the weight exceeds 2 tons.

PURIFICATION OF THE SEWAGE OF WATERBURY, Conn., is recommended in a report just made by Mr. Rudolph Hering, M. Am. Soc. C. E. Two plans are reported as feasible: Intermittent filtration on 100 acres of land, nine miles from the city, or combined chemical precipitation and filtration, using for the latter 33 acres of land 1.4 miles distant. In either case a 40-in. outlet sewer would be required for an estimated daily flow of 17,000,000 gallons. This allows about 85 gallons of sewage per day for 75,000 people, together with a considerable amount of surface water. The filtration plans calls for a present outlay of $609,730 and yearly charges of $28,489; a final outlay of $767,580 and yearly charges of $40,000; the average yearly charges being $34,246. The combined precipitation and filtration plan could be carried out for an initial outlay of only $138,380, and at an ultimate cost of $336,270; the yearly charges would range from $21,335 at the outset to $59,569 at the finish, with an average of $40,452. The low first cost of construction and operation under the second plan is due to the possibility of entirely omitting filtration for a time.

A 59-STORY BUILDING was announced to be under contemplation by the New York "Evening World" of Nov. 27. This veracious sheet went so far as to publish an elevation and plan of the structure, and stated that "the plans have been prepared by the firm of Chadwick & Wilbert, of the Bennett Building." A visit of a member of the staff of Engineering News to the Bennett Building showed that no such firm had offices there, and their names do not appear in the city directory. The description in "The World" stated that the building was to have seven sub-cellars; the outside was to be "of sheet-iron sheathed with brownstone," and the interior "furnished in Italian marble and brass." This charming structure was to be located at the corner of Tenth Ave. and 25th St., a locality where even an ordinary skyscraper would be absurd from the investors' point of view. We feel like begging our readers' pardon for paying any attention to this fake story in our columns, but we are aware that in many parts of the country, where "the new journalism" is not yet fully understood, people sometimes believe such newspaper fictions as the above.

A WATERFALL 1,600 FT. HIGH is reported as having been found in Venezuela by Mr. Donald Grant, of the Orinoco Company. A letter written from Santa Catalina, Venezuela, by S. A. Thompson, C. E., of Duluth, says that during the explorations of a concession to this company, in the Imataca Mountains, a large river was discovered cutting diagonally through an almost perpendicular cliff, estimated as being 1,600 ft. high. The water breaks into a dozen different streams, and spreads out in "fanlike expansions." This is at least interesting—if true.

WAR ON BRITISH DREDGES has been declared by some of the leading dredging companies of the United States. These companies have filed protests at Washington against permitting dredges from Canada working upon the government contract in Delaware River and Bay. The dredge lately towed from Montreal has been seized by the Philadelphia custom officials for violating the customs laws of the United States. Other dredges are on their way from Canada. A transfer to American owners is now being examined by the authorities, the new owners claiming that they thus have the right to use the plant in American waters. At the bottom of this trouble lies a row between rival American dredging companies and contractors for dredging.

AN AMERICAN PAPER-MAKING MACHINE is to be set up in the "Daily Chronicle" paper mill, at Sittingbourne, England. The machine is furnished with all the latest improvements and is said to be the first paper machine ever sent to England.

THE TOTAL JAPANESE RAILWAY MILEAGE, on March 1, 1896, was 2,290 miles, says Consul Uchida. At the same time 1,368 miles more were under construction and charters have been applied for covering an additional 655 miles. A ship-canal, from Osaka, across to the west coast of the island, is also under discussion. The actual cutting would be about 22 miles, and the river Uji and 9 miles of Lake Biwa would be included in the route. The Japan Mail Steamship Company, which recently opened a line to Seattle, has established a monthly service between Yokohama and Sidney and other Australian ports, and another Australian line is projected. The annual report of the Japanese Bureau of Merchant Marine shows that Japan has registered for foreign trade 109 iron and steel steamships, of 231,139 gross tons. Since 1890 twenty shipyards have been established in Japan, and 40 were started in the previous decade. The stone dry-dock at Nagasaki is 428 ft. long and 26 ft. deep. The Japanese subsidy law, which went into effect last October, gives shipbuilders a bounty of $10 per gross ton on steel vessels over 1,000 tons, and grants also $2.50 per horse-power.

THE CHINESE-RUSSIAN TREATY, reported as lately confirmed, grants important railway and other concessions to Russia, permitting that government to build its Trans-Siberian railway across Chinese territory, in Manchuria; to guard the railway with troops; to build other railways for China, terminating at Port Arthur, and to mine and transact other business. The representatives of other nations are inclined to publicly minimize the import of these concessions. Some of the lines of railways referred to will not be completed for two years, and others are only projected. They say that while the treaty gives Russia power to station troops in Chinese territory, it is not believed that this will be done except in urgent cases as such action would be regarded by other powers as a dangerous menace to their interests. But the same powers practically admit that Russia now politically dominates all China; though they say that England still holds the commercial supremacy.

GOVERNMENT CONTROL OF RAILWAYS has been mainly unsuccessful from an economic point of view in South America, and it is said that the Brazilian Congress will lease the Brazilian Central Ry. (operating 500 miles) to a foreign syndicate, the price being $90,000,000 for a 90-year lease. Under the imperial government this line was styled the Don Pedro Segundo Ry. It is charged that employment on the road has been given as a reward for political activity, the partisans of one party succeeding each other with the various changes of administration. In many cases the salaries were largely disproportionate to the character of the service performed, while in nearly every case except where experts were employed the appointees were unfit for their places. The debates in the Congress, which disclosed these facts, also showed conclusively that the road, instead of being a paying investment, is steadily losing money at the rate of $2,000,000 a year.

THE PACIFIC CABLE BILL, advocated by the Pacific Cable Company, is to be pushed in the next Congress. This bill would authorize the Postmaster General to contract to pay $100,000 per year for 20 years, for the construction and operation of an electric submarine cable connecting San Francisco and Honolulu, and such places on the coasts of Japan and China as the company may select, with the approval of this government. The company is to deposit $100,000 in U. S. bonds, to be forfeited in case of nonfulfilment of contract. This contract would require the company to complete the line to Honolulu before Jan. 1, 1898, so that it be capable of transmitting not less than 15 words per minute; within one year thereafter the line to China and Japan must be built. The company may establish landing stations on the Midway Islands, between Hawaii and Japan, and belonging to the United States. U. S. government messages are to be transmitted free forever and to have preference, and the rate for ordinary messages between the United States and Japan and China shall not exceed $1.25 per word, and 35 cts. per word to Honolulu. Press rates shall not exceed one-fourth of the cost of private messages. The House Committee has reported favorably upon this bill. The length of the cable route would be 2,097 miles to Honolulu, and 6,500 miles to Japan; and with 16% of slack the cable itself would be about 7,500 nautical miles long. The cost of the cable and the necessary repair ship is estimated at $7,500,000. This would be the longest cable in the world, and the deepest soundings show 3,185 fathoms. The Pacific Cable Company is a New York State corporation, with $10,000,000 capital.

WIRES UNDERGROUND AT ST. LOUIS seems to be the order of the day, 14 applications for permits to put in conduit systems having been filed recently by light, telephone and other companies.

THE MEASUREMENT OF WATER FOR IRRIGATION.*

By J. B. Pope, C. E.

Introductory.

The question is often asked, what is a miner's inch? and the answer often given is, that "quantity of water which will flow through an aperture 1 in. square under a 4-in. pressure." Frequently the "authority" will call it a 6-in. pressure and sometimes the pressure-head is measured from the center of the aperture, or the top or bottom. Seldom is it stated whether the discharge is through a thin or thick plate, although this condition is a very important factor.

An attempt will be made in the following pages to demonstrate the importance of abolishing the "miner's inch," and adopting cubic feet per second as a unit of measurement for all water systems. Irrigating water will then assume a value according to quantity.

The principles of making distributions and constructing adjustable measuring weirs are original, and, as submitted, represent a considerable expenditure for testing and experimenting. The tables were carefully calculated and checked over, and their correctness demonstrated by many crucial tests.

Tables I. and II.

Table I. is simply a reduction of the California miner's inch, and the Colorado miner's inch, to cubic feet and acre feet for irrigating seasons of 3, 4, 5, 6 and 7 months, and every ten days thereof.

The Colorado miner's inch is equal to a flow of 1.56 cu. ft. per min., or .026 cu. ft. per sec., and 1 cu. ft. per sec. equals 38.46 Colorado miner's inches. (See report of State Engineer to Governor of Colorado for 1883 and 1884, page 60.)

The California miner's inch is equal to a flow of 1.2 cu. ft. per min., or .02 cu. ft. per sec., and 1 cu. ft. per sec. is equal to 50 California miner's inches. (See Irrigation in California, Wm. Ham. Hall, Part II., p. 27.)

The California miner's inch seems to be in greatest favor, possibly by reason of its convenience as a mathematical factor. In a few localities other values are adopted and called "miner's inches," but not to an extent worthy of notice.

The first left hand column of Table I. gives the number of days for irrigating seasons from 90 up to 210 days, or from 3 to 7 months. Opposite each irrigating season the double lines in the second column gives the quantity or value of a California miner's inch, flowing continuously for that length of time in the lower line, and the value of a Colorado miner's inch, flowing continuously for the same length of time is given in the upper line of the second column.

For example, one Colorado miner's inch flowing continuously for five months, or 150 days, equals 336,960 cu. ft., and one California miner's inch flowing continuously for five months, or 150 days, equals 259,200 cu. ft.

The other columns to the right give the values in acre feet for Colorado miner's inches above, and California miner's inches below, for the respective irrigation seasons, and continuous flow. Thus, with an irrigating season of six months, or 180 days, and a water right of one Colorado miner's inch continuous flow, we find in the first column six months, 180 days; opposite this, in the second column and above, we find 404,352, the quantity in cubic feet for that period of time; in the third column and above, we find its value 9,283 acre feet for one acre, or in the seventh column, which is headed 5A, we find 1.857, its value in acre feet for five acres, i. e., the depth in feet which one Colorado miner's inch, flowing continuously for 180 days, will cover one acre, or five acres, as the case may be. Opposite 180 days, in the column headed five acres, and on the lower line, we find 1.628, or the value in acre feet for one California miner's inch, flowing continuously for 180 days.

Table II. gives the required flow in cubic feet per second to cover one acre a given depth in one hour's time, or with from 1 to 30 irrigations of one hour each. The first column gives the number of irrigations during the entire season; the top line of figures gives the value of the water right in acre feet for the entire season, and the quantities below give the flow in cubic feet per second required to supply this water right, or any portion of it, in one hour of time. For example, with a water right of 1 acre foot, and an irrigation season of 180 days, it is desired to irrigate every nine days, allowing one hour constant flow for each acre, required the flow in cubic feet per second; we thus have 20 irrigations. Reading down the first column to the number 20, then to the right along this line to the column headed "1 acre foot," we find 0.605, the flow in cubic feet per second that will cover one acre 0.20-ft. deep in one hour of time.

Again, with a water right of 1.6 acre feet and ten irrigations during the entire season, required the flow in cubic feet per second for each irrigation to irrigate one acre in one hour of time. Find 10 in the first column opposite, and in column headed "1.6 acre feet" appear the figures 1.936, the flow in cubic feet per second required to cover one acre 0.16-ft. deep in one hour of time.

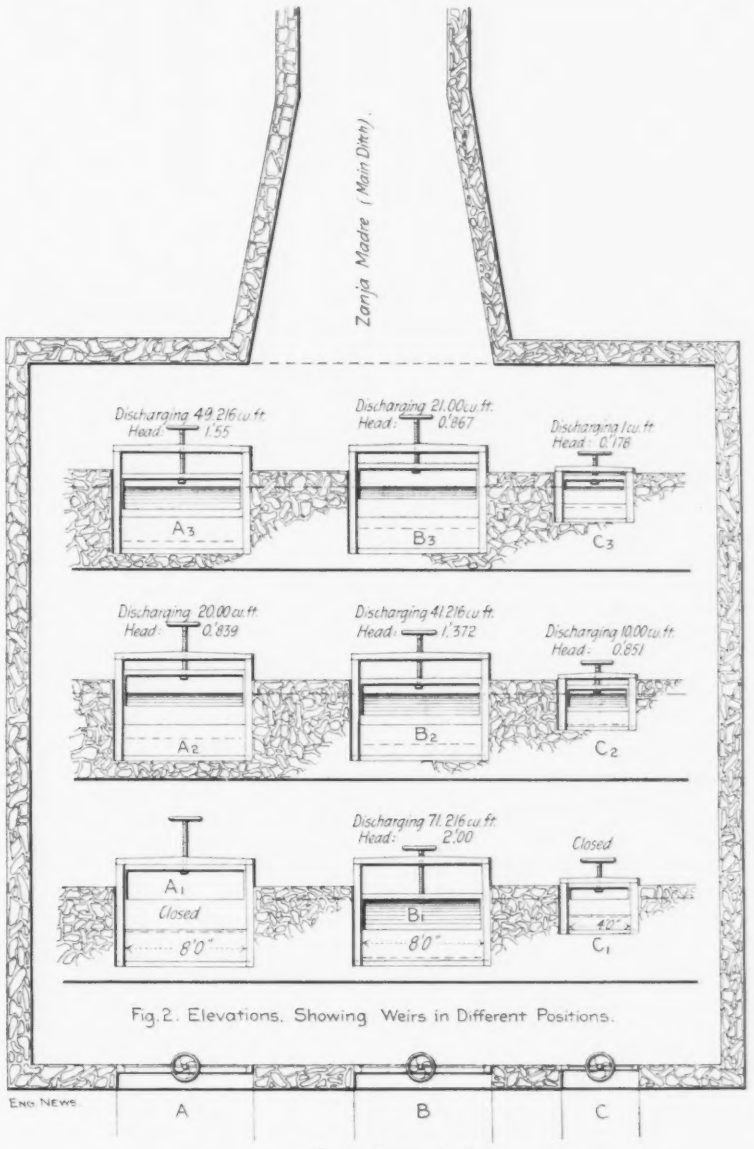
With Tables I. and II. we can readily reduce water rights quoted in Colorado or California miner's inches per acre to acre feet.

For example: With a water right of one Colorado miner's inch to eight acres during an irrigating season of five months, or 150 days, by Table I. we find that the total flow is 336,960 cu. ft., and that the value of the water right in acre feet is 0.967, which may be called 1 acre-ft. for all practical purposes, and with the aid of Table II. may be successfully delivered in any desired number of irrigations at the rate of one acre per hour, or any fraction or multiple thereof. The same is true with the California miner's inch. The water right being quoted in miner's inches per acre, we have only to follow the explanations given to find the tables applicable and sufficient for all ordinary cases.

The advantage of measuring and distributing irrigation water in cubic feet per second and in acre feet is obvious when compared with the troublesome and ambiguous "miner's inch" method. At present the policy of the irrigator is to irrigate as often and freely as possible, seldom admitting that the supply is sufficient. Little effort is made to determine the actual quantity of water required during an irrigating season to produce the best results for different crops and soils under cultivation. With water rights in acre feet, and the several distributions made in cubic feet per second, the user will, in the course of time, be enabled to determine many economical questions, such as the actual quantity of water required, number and time of deliveries for each crop, etc. There are few systems in operation at present that do not waste at least 40% of the supply, owing to ineffectual distributions and misleading measurements.

To make a practical and accurate distribution of the water flowing in a main irrigating canal so that one or more lateral canals will be supplied with certain quantities, while the remainder continues through the main canal, the maximum flow of main and laterals must first be determined, and the following requisite conditions complied with:

For a short distance immediately above the distribution box the cross-section of the main canal must be enlarged, and the grade flattened, so that the velocity will not exceed 1 ft. per sec. where it enters the distribution box. This box should be



ELEVATION AND PLAN OF ADJUSTABLE DISTRIBUTING WEIRS.
J. B. Pope, Engineer, San Bernardino Cal.

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square, as shown in Fig. 1, with the sides equal to four times the length of the longest weir required. The depth should equal the length of the longest weir measuring down from its crest. Should the water carry a perceptible amount of silt the depth should be increased. Let the spillway equal twice the maximum head of its respective weir, measuring down from the crest. This will allow a free discharge. The weirs may be placed in the wall opposite the inflow, with small weirs on either side of the greater.

Great care must be exercised in placing the weirs, the crest of each being exactly its maximum head below the surface of the intake during a maximum flow. This done, there will be no material acceleration of flow from the intake through the weir box to the discharging weirs. A datum point must then be established on the working surface of the box, on the level of the water at the intake and working head of the weirs, and should be located at the middle of either side of the weir box. This point is the hydraulic head of all of the weirs when the requisite conditions have been attained in the weir box, which then becomes a still pond.

The writer has designed and tested a very satisfactory weir, consisting of a rectangular weir-plate that is raised and lowered by means of a screw. The water in the division box presses the weir-plate against the frame and fixed plate, making water-tight bearings. The weir-plate is flush with the inside wall of the division box; the uprights of the fixed frame are channeled to receive the beveled edge and uprights of the weir-plate. The length of the crest should be even feet.

A graduated scale of a special design should then be placed on one or both of the fixed uprights, the vernier for the scale being fixed on the upright of the movable weir-plate. The lower end of the screw acts as a swivel in the horizontal member that carries the weir-plate. The upper horizontal member of the frame is fixed firmly, and is threaded to carry the screw which governs the weir-plate. A datum point with graduated scale and vernier is then set in the division box on a level with the crest of the weir when it is closed up, and its scale reading zero.

We are then ready for

Table III.

This table gives the discharge in cubic feet per second for rectangular weirs of several lengths, with end contractions, for heads of every .001 ft. from .01 up to one-fourth the length of the weir. It is based upon the well-known weir formula of the late J. B. Francis, i. e.: Discharge in cubic feet per second $= 3.33 \times \left|\begin{array}{c}\text{length of weir,}\\ \text{minus 1-5th head}\end{array}\right| \times \sqrt{\text{cube}}$ of head, special notice being taken of his statement that "where more than common accuracy is aimed at, we may take co-efficients between 3.41 and 3.33 for heads betwen ½-in. and 5 ins., and 3.3 instead of 3.33 for heads greater than 2 ft. (Trautwine, 13th ed., p. 265.)

The coefficients used in calculating the table were obtained by interpolation in accordance with the above suggestion.

The correctness of this method the writer demonstrated to his satisfaction by placing a number of weirs of various lengths continuously one upstream above the other in a cemented canal. The weirs were so placed that all requisite conditions regarding still water and spillways were obtained. The respective heads were determined with needle-point gages, on the plan of hook gages. These experiments were often repeated during the summer of 1894, and always with satisfactory results. Thus encouraged, the task of completing the table was cheerfully resumed. Figures for 1, 1½, 2, 3, 4, 5, 6, 8 and 10-ft. weirs are given.

(To reduce the weir discharge given in the tables to California miner's inches, we have only to multiply the quantity given by the constant 50. Multiplying by 38.46 the result will be in Colorado miner's inches.)

Fig. 2 shows three of these weirs in a division box, two 8 and one 4-ft. A1 and C1 are closed. B1 is discharging 71.216 cu. ft. per sec. The scale on the upright reads 2 ft. even. The line indicating the surface, or hydraulic head, is at zero, the datum point. In the second series, A2 has been lowered by means of the screw until its graduated scale reads 0.839, and is discharging 20 cu. ft. per sec. B2 has been raised, its scale reading 1.372, and is discharging 41.216, according to the part of the table for 8-ft. weirs. C2 is now discharging 10 cu. ft. per sec.,its scale reading 0.851 nearly, according to the part of the table for 4-ft. weirs. The datum line, or hydraulic head, is unchanged.

A third distribution is shown by A3, B3 and C3, the hydraulic head remaining unchanged. A3 discharges 49.216 cu. ft. per sec., with a head of 1.55 nearly. B3 discharges 21 cu. ft. per sec., under a head of 0.867, and C3 discharges 1 cu. ft. per sec., with a head of 0.178. The scale in all cases gives the head, feet and decimal parts thereof, the first column giving feet and hundredths thereof, the thousandths being indicated at the top.

The graduated scale attached to the zero point, which is the hydraulic head, is used only when an increase in the flow occurs unexpectedly. When this happens, it is only necessary to measure up by means of this scale. This increased head is added to the head of each of the weirs, the several flows noted and corrected by adjusting one of the weirs, so that it will take the surplus in addition to its previous flow. This done the others carry their required volumes, and the hydraulic head soon settles back to its proper place. When a deficiency occurs, it but remains to raise whichever weir is to lose it, according to the amount of the deficiency, then the hydraulic head is quickly resumed. Thus it is seen that there is no limit to the relative proportion of distributions that may be made with this method.

The first cost does not exceed very materially that of less satisfactory division boxes. The weirs are durable, and can be made of wood, or iron, or brass. The graduated scales can be obtained at very reasonable figures from Mr. J. C. Sala, 429 Montgomery St., San Francisco, Cal. The author will supply plans and specifications, or furnish weirs of all sizes, place and test them, guaranteeing satisfactory results.

TABLE I.—Values of California and Colorado Miner's Inches in Cubic Feet and Acre-Feet for Various Periods.

Acres			Value of mnr's ins. in cu. ft.*	Values of Colorado and California miner's inches in acre-feet														
				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
80	days	....Colorado.....	202,176	4.641	2.320	1.547	1.160	0.928	0.774	0.663	0.580	0.516	0.464	0.422	0.387	0.357	0.332	0.309
90	"	....California.....	155,520	3.570	1.785	1.190	0.892	0.714	0.595	0.510	0.446	0.397	0.357	0.325	0.297	0.275	0.255	0.238
100	"	....Colorado.....	224,640	5.157	2.578	1.719	1.289	1.031	0.860	0.737	0.645	0.573	0.516	0.469	0.430	0.397	0.368	0.344
100	"	....California.....	172,800	3.967	1.983	1.322	0.991	0.793	0.662	0.567	0.496	0.441	0.397	0.361	0.331	0.305	0.283	0.264
110	"	....Colorado.....	247,104	5.673	2.836	1.891	1.418	1.135	0.946	0.810	0.709	0.630	0.567	0.516	0.473	0.436	0.406	0.378
110	"	....California.....	190,080	4.364	2.182	1.454	1.091	0.873	0.727	0.623	0.545	0.485	0.436	0.397	0.364	0.336	0.312	0.291
120	"	....Colorado.....	269,568	6.188	3.094	2.063	1.547	1.238	1.031	0.884	0.773	0.688	0.619	0.563	0.516	0.476	0.442	0.413
120	"	....California.....	207,360	4.760	2.380	1.587	1.190	0.952	0.793	0.680	0.595	0.529	0.476	0.433	0.397	0.366	0.340	0.317
130	"	....Colorado.....	292,032	6.704	3.352	2.235	1.676	1.341	1.117	0.958	0.837	0.745	0.670	0.610	0.506	0.516	0.479	0.447
130	"	....California.....	224,640	5.157	2.578	1.719	1.289	1.031	0.859	0.737	0.645	0.573	0.516	0.469	0.430	0.397	0.368	0.344
140	"	....Colorado.....	314,496	7.220	3.610	2.407	1.805	1.444	1.203	1.031	0.903	0.802	0.722	0.656	0.602	0.555	0.516	0.481
140	"	....California.....	241,920	5.554	2.777	1.851	1.388	1.111	0.926	0.793	0.694	0.617	0.555	0.505	0.463	0.426	0.397	0.370
150	"	....Colorado.....	336,960	7.735	3.867	2.578	1.934	1.547	1.290	1.105	0.967	0.860	0.774	0.703	0.645	0.595	0.552	0.516
150	"	....California.....	259,200	5.950	2.975	1.983	1.488	1.190	0.991	0.850	0.743	0.661	0.595	0.541	0.496	0.458	0.425	0.397
160	"	....Colorado.....	359,424	8.251	4.125	2.750	2.063	1.650	1.376	1.179	1.031	0.917	0.825	0.750	0.688	0.635	0.589	0.550
160	"	....California.....	276,480	6.347	3.173	2.116	1.587	1.269	1.059	0.907	0.793	0.705	0.635	0.577	0.529	0.488	0.453	0.423
170	"	....Colorado.....	381,888	8.767	4.383	2.922	2.192	1.753	1.461	1.253	1.096	0.974	0.878	0.797	0.731	0.675	0.626	0.585
170	"	....California.....	293,760	6.744	3.372	2.248	1.686	1.349	1.124	0.963	0.843	0.749	0.674	0.613	0.562	0.519	0.482	0.450
180	"	....Colorado.....	404,352	9.283	4.641	3.094	2.321	1.857	1.547	1.326	1.160	1.031	0.928	0.844	0.774	0.714	0.663	0.619
180	"	....California.....	311,040	7.140	3.570	2.380	1.785	1.428	1.190	1.020	0.892	0.793	0.714	0.649	0.595	0.549	0.510	0.476
190	"	....Colorado.....	426,816	9.798	4.899	3.266	2.450	1.960	1.634	1.400	1.225	1.089	0.980	0.890	0.817	0.754	0.700	0.653
190	"	....California.....	328,320	7.537	3.769	2.512	1.884	1.507	1.256	1.077	0.942	0.837	0.754	0.685	0.628	0.580	0.538	0.502
200	"	....Colorado.....	449,280	10.314	5.157	3.438	2.578	2.063	1.719	1.473	1.289	1.146	1.031	0.938	0.860	0.794	0.737	0.688
200	"	....California.....	345,600	7.934	3.967	2.645	1.983	1.587	1.322	1.133	0.992	0.881	0.793	0.721	0.661	0.610	0.567	0.529
210	"	....Colorado.....	471,744	10.830	5.415	3.610	2.707	2.166	1.806	1.547	1.353	1.203	1.083	0.984	0.903	0.833	0.774	0.722
210	"	....California.....	362,880	8.331	4.165	2.777	2.083	1.666	1.388	1.190	1.041	0.926	0.833	0.757	0.694	0.641	0.595	0.555

*A continuous flow of 1 in. for the period named in the first column.

TABLE II.—Required Flow in Cubic Feet per Second to Cover One Acre a Given Depth in from 1 to 30 Hours.

Total hours.*	Depth in acre-feet for irrigating season.															
	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0
	Flow in cubic feet per second to cover one acre a given depth in one hour of time.															
1	6.050	7.260	8.470	9.680	10.890	12.100	13.310	14.520	15.730	16.940	18.150	19.360	20.570	21.780	22.990	24.200
2	3.025	3.630	4.235	4.840	5.445	6.050	6.655	7.260	7.865	8.470	9.075	9.680	10.285	10.890	11.495	12.100
3	2.017	2.420	2.823	3.227	3.630	4.033	4.437	4.840	5.243	5.647	6.050	6.453	6.857	7.260	7.663	8.066
4	1.512	1.815	2.117	2.420	2.722	3.025	3.327	3.630	3.932	4.235	4.537	4.840	5.142	5.445	5.747	6.050
5	1.210	1.452	1.694	1.936	2.178	2.420	2.662	2.904	3.146	3.388	3.630	3.872	4.114	4.354	4.598	4.840
6	1.010	1.210	1.411	1.613	1.815	2.016	2.218	2.420	2.622	2.823	3.025	3.227	3.428	3.630	3.831	4.033
7	0.864	1.037	1.210	1.383	1.556	1.728	1.901	2.074	2.247	2.420	2.593	2.766	2.938	3.111	3.284	3.457
8	0.756	0.907	1.059	1.210	1.361	1.512	1.664	1.815	1.966	2.117	2.269	2.420	2.571	2.722	2.874	3.025
9	0.672	0.806	0.941	1.076	1.210	1.344	1.479	1.613	1.748	1.882	2.017	2.151	2.285	2.420	2.554	2.689
10	0.605	0.726	0.847	0.968	1.089	1.210	1.331	1.452	1.573	1.694	1.815	1.936	2.057	2.178	2.299	2.420
11	0.550	0.660	0.770	0.880	0.990	1.100	1.210	1.320	1.430	1.540	1.650	1.760	1.870	1.980	2.090	2.200
12	0.504	0.605	0.706	0.807	0.908	1.008	1.109	1.210	1.311	1.412	1.512	1.613	1.714	1.815	1.916	2.017
13	0.465	0.558	0.651	0.745	0.838	0.931	1.024	1.117	1.210	1.303	1.396	1.489	1.582	1.675	1.768	1.860
14	0.432	0.519	0.605	0.691	0.778	0.864	0.951	1.030	1.124	1.210	1.296	1.383	1.470	1.556	1.642	1.728
16	0.378	0.454	0.529	0.605	0.681	0.756	0.832	0.907	0.983	1.059	1.134	1.210	1.286	1.361	1.436	1.513
18	0.336	0.403	0.471	0.538	0.605	0.672	0.739	0.807	0.874	0.941	1.008	1.076	1.143	1.210	1.277	1.344
20	0.302	0.363	0.423	0.484	0.544	0.605	0.665	0.726	0.786	0.847	0.907	0.968	1.028	1.089	1.149	1.210
22	0.229	0.330	0.382	0.440	0.495	0.550	0.605	0.660	0.715	0.770	0.825	0.880	0.935	0.990	1.045	1.100
24	0.252	0.302	0.353	0.403	0.454	0.504	0.554	0.605	0.655	0.706	0.756	0.807	0.857	0.908	0.958	1.008
26	0.232	0.279	0.326	0.372	0.419	0.465	0.512	0.558	0.605	0.651	0.698	0.745	0.791	0.838	0.884	0.931
28	0.216	0.259	0.302	0.345	0.389	0.432	0.475	0.519	0.562	0.605	0.648	0.691	0.734	0.778	0.821	0.864
30	0.202	0.242	0.282	0.323	0.363	0.403	0.443	0.484	0.524	0.565	0.605	0.645	0.686	0.726	0.766	0.807

*Or the number of irrigations during the season.

TABLE III.—DISCHARGE IN CUBIC FEET PER SECOND FOR WEIRS WITH END CONTRACTIONS FOR LENGTHS OF FROM 1 TO 10 FT., AND HEADS OF FROM 0.010 TO ONE-FOURTH THE LENGTH OF THE WEIRS.

1-Ft. Weir.

Head in ft.	0	1	2	3	4	5	6	7	8	9
.01..	.003	.004	.004	.005	.006	.006	.007	.008	.009	.009
.02..	.010	.011	.011	.012	.013	.013	.014	.015	.016	.016
.03..	.017	.018	.019	.020	.021	.022	.023	.024	.025	.026
.04..	.027	.028	.029	.030	.031	.032	.033	.034	.035	.036
.05..	.037	.038	.039	.041	.042	.044	.045	.046	.047	.048
.06..	.049	.050	.052	.053	.054	.055	.057	.058	.059	.060
.07..	.062	.063	.065	.066	.067	.068	.070	.071	.073	.074
.08..	.075	.076	.078	.079	.081	.082	.084	.085	.087	.088
.09..	.090	.091	.093	.094	.096	.097	.099	.100	.102	.103
.10..	.105	.106	.108	.110	.111	.113	.115	.116	.118	.119
.11..	.121	.123	.124	.126	.127	.129	.131	.132	.134	.135
.12..	.137	.139	.140	.142	.144	.145	.147	.149	.151	.152
.13..	.154	.156	.157	.159	.161	.163	.165	.167	.168	.170
.14..	.172	.174	.176	.177	.179	.181	.183	.185	.186	.188
.15..	.190	.193	.195	.196	.198	.200	.202	.204	.205	.207
.16..	.209	.211	.213	.215	.217	.218	.220	.222	.224	.226
.17..	.228	.230	.232	.234	.236	.238	.240	.242	.244	.246
.18..	.248	.250	.252	.254	.256	.258	.261	.263	.265	.267
.19..	.269	.271	.273	.275	.277	.279	.282	.284	.286	.288
.20..	.290	.292	.294	.296	.298	.300	.302	.304	.306	.308
.21..	.311	.313	.315	.317	.319	.321	.324	.326	.328	.330
.22..	.332	.334	.336	.338	.341	.343	.345	.347	.350	.352
.23..	.354	.356	.358	.361	.363	.365	.367	.369	.372	.374
.24..	.376	.378	.381	.383	.385	.387	.390	.392	.394	.397
.25..	.400	.402	.405	.407	.410	.412	.414	.417	.419	.422

TABLE III.—(Continued.)

1½-Ft. Weir.

Head in ft.	0	1	2	3	4	5	6	7	8	9
.01..	.005	.006	.007	.008	.009	.009	.010	.011	.012	.013
.02..	.014	.015	.016	.018	.019	.020	.021	.022	.024	.025
.03..	.026	.027	.029	.030	.031	.033	.034	.036	.037	.039
.04..	.040	.042	.043	.045	.047	.048	.050	.052	.054	.055
.05..	.057	.059	.060	.062	.064	.065	.067	.069	.071	.072
.06..	.074	.076	.078	.080	.082	.083	.085	.087	.089	.091
.07..	.093	.095	.097	.099	.101	.103	.106	.108	.110	.112
.08..	.114	.116	.118	.121	.123	.125	.127	.129	.132	.134
.09..	.136	.138	.141	.143	.145	.147	.150	.152	.154	.157
.10..	.159	.161	.164	.166	.169	.171	.173	.176	.178	.181
.11..	.183	.185	.188	.190	.193	.195	.198	.200	.203	.205
.12..	.208	.211	.213	.216	.218	.221	.224	.226	.229	.231
.13..	.234	.237	.239	.242	.245	.247	.250	.253	.256	.258
.14..	.261	.264	.267	.269	.272	.275	.278	.281	.283	.286
.15..	.289	.292	.295	.297	.300	.303	.306	.309	.311	.314
.16..	.317	.320	.323	.326	.329	.332	.335	.338	.341	.344
.17..	.347	.350	.353	.356	.359	.362	.365	.368	.371	.374
.18..	.377	.380	.383	.386	.389	.392	.395	.398	.401	.404
.19..	.408	.411	.414	.418	.421	.424	.427	.430	.434	.437
.20..	.440	.443	.446	.449	.453	.456	.459	.463	.466	.469
.21..	.473	.476	.480	.483	.486	.489	.493	.496	.499	.503
.22..	.506	.509	.513	.516	.520	.523	.526	.530	.533	.537
.23..	.540	.543	.547	.550	.554	.557	.560	.564	.567	.571
.24..	.574	.577	.581	.584	.588	.591	.595	.598	.602	.605
.25..	.609	.613	.616	.620	.623	.627	.631	.634	.638	.641
.26..	.645	.649	.652	.656	.659	.663	.667	.670	.674	.677
.27..	.681	.685	.688	.692	.696	.699	.703	.707	.711	.714
.28..	.718	.722	.725	.729	.733	.736	.740	.744	.748	.751
.29..	.755	.759	.763	.766	.770	.774	.778	.782	.785	.789
.30..	.793	.797	.801	.804	.808	.812	.816	.820	.823	.827
.31..	.831	.835	.839	.843	.847	.850	.854	.858	.862	.866
.32..	.870	.874	.878	.882	.886	.889	.893	.897	.901	.905
.33..	.909	.913	.917	.921	.925	.929	.933	.937	.941	.945
.34..	.949	.953	.957	.961	.965	.969	.973	.977	.981	.985
.35..	.989	.993	.997	1.001	1.005	1.009	1.013	1.017	1.021	1.025
.36..	1.030	1.034	1.038	1.042	1.046	1.050	1.055	1.059	1.063	1.067
.37..	1.071	1.075	1.079	1.084	1.088	1.092	1.096	1.100	1.105	1.109
.38..	1.113	1.117	1.121	1.126	1.130	1.134	1.139	1.142	1.147	1.151
.39..	1.115	1.159	1.163	1.168	1.172	1.176	1.180	1.184	1.189	1.193
.40..	1.197	1.201	1.206	1.210	1.214	1.218	1.223	1.227	1.231	1.236

TABLE III.—(Continued.)

2-Ft. Weir.

Head in ft.	0	1	2	3	4	5	6	7	8	9
.01..	.007	.008	.009	.011	.012	.013	.014	.015	.017	.018
.02..	.019	.021	.022	.024	.025	.027	.029	.030	.032	.033
.03..	.035	.037	.039	.041	.043	.044	.046	.048	.050	.052
.04..	.054	.056	.058	.060	.062	.064	.067	.069	.071	.073
.05..	.075	.077	.080	.082	.085	.087	.089	.092	.094	.097
.06..	.099	.102	.104	.107	.109	.112	.115	.117	.120	.122
.07..	.125	.128	.130	.133	.136	.138	.141	.144	.147	.149
.08..	.152	.155	.158	.161	.164	.167	.170	.173	.176	.179
.09..	.182	.185	.188	.191	.194	.197	.200	.203	.206	.209
.10..	.212	.215	.219	.222	.225	.228	.232	.235	.238	.242
.11..	.245	.248	.252	.255	.258	.262	.265	.268	.272	.275
.12..	.278	.281	.285	.288	.292	.295	.299	.302	.305	.309
.13..	.313	.317	.320	.324	.328	.331	.335	.339	.343	.346
.14..	.350	.354	.357	.361	.365	.368	.372	.376	.380	.383
.15..	.387	.391	.395	.398	.402	.406	.410	.414	.417	.421
.16..	.425	.429	.433	.437	.441	.445	.449	.453	.457	.461
.17..	.465	.469	.473	.477	.481	.485	.490	.494	.498	.502
.18..	.506	.510	.514	.519	.523	.527	.531	.535	.540	.544
.19..	.548	.552	.557	.561	.565	.569	.574	.578	.582	.587
.20..	.591	.595	.600	.604	.609	.613	.617	.622	.626	.631
.21..	.635	.639	.644	.648	.653	.657	.662	.666	.671	.675
.22..	.680	.684	.689	.693	.698	.702	.707	.711	.716	.720
.23..	.725	.730	.734	.739	.744	.748	.753	.758	.763	.767
.24..	.772	.777	.782	.786	.791	.796	.801	.806	.810	.815
.25..	.820	.825	.830	.834	.839	.844	.849	.854	.858	.863
.26..	.868	.873	.878	.883	.888	.892	.897	.902	.907	.912
.27..	.917	.922	.927	.932	.937	.942	.947	.952	.957	.962
.28..	.967	.972	.977	.982	.987	.992	.997	1.002	1.007	1.012
.29..	1.017	1.022	1.027	1.033	1.038	1.043	1.048	1.053	1.059	1.064
.30..	1.069	1.074	1.079	1.085	1.090	1.095	1.100	1.105	1.111	1.116
.31..	1.121	1.126	1.132	1.137	1.142	1.147	1.153	1.158	1.163	1.169
.32..	1.174	1.179	1.185	1.190	1.195	1.200	1.206	1.211	1.216	1.222
.33..	1.227	1.232	1.238	1.243	1.249	1.254	1.259	1.265	1.270	1.276
.34..	1.281	1.286	1.292	1.297	1.303	1.308	1.314	1.319	1.325	1.330
.35..	1.336	1.341	1.347	1.352	1.358	1.363	1.369	1.374	1.380	1.385
.36..	1.391	1.396	1.402	1.408	1.413	1.419	1.425	1.430	1.436	1.441
.37..	1.447	1.453	1.458	1.464	1.469	1.475	1.481	1.486	1.492	1.497
.38..	1.503	1.509	1.515	1.520	1.526	1.532	1.538	1.544	1.549	1.555
.39..	1.561	1.567	1.573	1.578	1.584	1.590	1.596	1.602	1.607	1.613
.40..	1.619	1.625	1.631	1.637	1.643	1.648	1.654	1.660	1.667	1.672
.41..	1.678	1.684	1.690	1.696	1.702	1.707	1.713	1.719	1.725	1.731
.42..	1.737	1.743	1.749	1.755	1.761	1.767	1.773	1.779	1.785	1.791
.43..	1.797	1.803	1.809	1.815	1.821	1.827	1.833	1.840	1.846	1.852
.44..	1.858	1.864	1.870	1.876	1.882	1.888	1.895	1.901	1.907	1.913
.45..	1.919	1.925	1.932	1.938	1.994	1.950	1.957	1.963	1.969	1.976
.46..	1.982	1.988	1.995	2.001	2.007	2.013	2.020	2.026	2.032	2.039
.47..	2.045	2.051	2.058	2.064	2.070	2.076	2.083	2.089	2.095	2.102
.48..	2.108	2.114	2.121	2.127	2.134	2.140	2.146	2.153	2.159	2.166
.49..	2.172	2.178	2.185	2.191	2.198	2.204	2.210	2.217	2.223	2.230
.50..	2.236	2.242	2.249	2.255	2.262	2.268	2.274	2.281	2.287	2.294

TABLE III.—(Continued.)

3-Ft. Weir.

Head in ft.	0	1	2	3	4	5	6	7	8	9
.01..	.010	.012	.013	.015	.017	.018	.020	.022	.024	.025
.02..	.027	.029	.032	.034	.037	.039	.041	.044	.046	.049
.03..	.051	.054	.057	.060	.063	.066	.069	.072	.075	.078
.04..	.081	.084	.087	.091	.094	.097	.100	.103	.107	.110
.05..	.113	.117	.120	.124	.127	.131	.135	.138	.142	.145
.06..	.149	.153	.157	.161	.165	.168	.172	.176	.180	.184
.07..	.188	.192	.196	.200	.204	.208	.213	.217	.221	.225
.08..	.229	.233	.238	.242	.247	.251	.255	.260	.264	.269
.09..	.273	.278	.282	.287	.292	.296	.301	.306	.311	.315
.10..	.320	.325	.330	.334	.339	.344	.349	.354	.358	.363
.11..	.368	.373	.378	.383	.388	.393	.399	.404	.409	.414
.12..	.419	.424	.430	.435	.440	.445	.451	.456	.461	.467
.13..	.472	.477	.483	.488	.494	.499	.505	.510	.516	.521
.14..	.527	.533	.538	.544	.549	.555	.561	.566	.572	.577
.15..	.583	.589	.595	.601	.607	.612	.618	.624	.630	.636
.16..	.642	.648	.654	.660	.666	.672	.678	.684	.690	.696
.17..	.702	.708	.714	.720	.727	.733	.739	.745	.762	.758
.18..	.764	.770	.777	.783	.789	.795	.802	.808	.815	.821
.19..	.827	.833	.840	.846	.853	.859	.866	.872	.879	.885
.20..	.892	.899	.905	.912	.918	.925	.932	.938	.945	.951
.21..	.958	.965	.972	.979	.986	.992	.999	1.006	1.013	1.020
.22..	1.027	1.034	1.041	1.048	1.055	1.062	1.069	1.076	1.083	1.090
.23..	1.097	1.104	1.111	1.118	1.125	1.132	1.139	1.146	1.153	1.160
.24..	1.167	1.174	1.182	1.189	1.196	1.203	1.211	1.218	1.225	1.233
.25..	1.240	1.247	1.255	1.262	1.269	1.276	1.284	1.291	1.298	1.306
.26..	1.313	1.320	1.328	1.335	1.343	1.350	1.358	1.365	1.373	1.380
.27..	1.388	1.396	1.403	1.411	1.418	1.426	1.434	1.441	1.449	1.456
.28..	1.464	1.472	1.479	1.487	1.495	1.502	1.510	1.518	1.526	1.533
.29..	1.541	1.549	1.557	1.564	1.572	1.580	1.588	1.596	1.603	1.611
.30..	1.619	1.627	1.635	1.643	1.651	1.659	1.667	1.675	1.683	1.691
.31..	1.699	1.707	1.715	1.723	1.731	1.739	1.747	1.755	1.763	1.771
.32..	1.779	1.787	1.795	1.804	1.812	1.820	1.828	1.836	1.845	1.853
.33..	1.861	1.869	1.877	1.886	1.894	1.902	1.910	1.918	1.927	1.935
.34..	1.943	1.951	1.960	1.968	1.977	1.985	1.993	2.002	2.010	2.019
.35..	2.027	2.035	2.044	2.052	2.061	2.069	2.078	2.086	2.095	2.103
.36..	2.112	2.121	2.129	2.138	2.146	2.155	2.164	2.172	2.181	2.189
.37..	2.198	2.207	2.215	2.224	2.233	2.241	2.250	2.259	2.268	2.276
.38..	2.285	2.294	2.303	2.311	2.320	2.329	2.338	2.347	2.355	2.364
.39..	2.373	2.382	2.391	2.399	2.408	2.417	2.426	2.435	2.443	2.452
.40..	2.461	2.470	2.479	2.488	2.497	2.506	2.515	2.524	2.533	2.542
.41..	2.552	2.560	2.569	2.578	2.588	2.597	2.606	2.615	2.624	2.634
.42..	2.643	2.652	2.662	2.671	2.680	2.689	2.699	2.708	2.717	2.727
.43..	2.736	2.745	2.755	2.764	2.773	2.783	2.792	2.802	2.811	2.820
.44..	2.830	2.839	2.849	2.858	2.868	2.877	2.887	2.896	2.906	2.915
.45..	2.925	2.934	2.944	2.953	2.963	2.972	2.982	2.991	3.001	3.010
.46..	3.020	3.030	3.039	3.049	3.059	3.068	3.078	3.088	3.098	3.107
.47..	3.117	3.127	3.137	3.146	3.156	3.166	3.176	3.186	3.195	3.205
.48..	3.215	3.225	3.235	3.245	3.255	3.264	3.274	3.284	3.294	3.304
.49..	3.314	3.324	3.334	3.344	3.354	3.363	3.373	3.383	3.393	3.403
.50..	3.413	3.423	3.433	3.443	3.453	3.463	3.473	3.483	3.493	3.503
.51..	3.513	3.523	3.533	3.543	3.553	3.563	3.574	3.584	3.594	3.604
.52..	3.614	3.624	3.634	3.645	3.655	3.665	3.675	3.685	3.696	3.706
.53..	3.716	3.726	3.737	3.747	3.757	3.767	3.778	3.788	3.798	3.809
.54..	3.819	3.829	3.840	3.850	3.860	3.870	3.881	3.891	3.901	3.912
.55..	3.922	3.932	3.943	3.953	3.964	3.974	3.985	3.995	4.006	4.016
.56..	4.027	4.037	4.048	4.058	4.069	4.079	4.090	4.100	4.111	4.121
.57..	4.132	4.142	4.153	4.164	4.174	4.185	4.196	4.206	4.217	4.227
.58..	4.238	4.249	4.259	4.270	4.281	4.291	4.302	4.313	4.324	4.334
.59..	4.345	4.356	4.367	4.377	4.388	4.399	4.410	4.421	4.431	4.442
.60..	4.453	4.464	4.475	4.486	4.497	4.507	4.518	4.529	4.540	4.551
.61..	4.562	4.573	4.584	4.595	4.606	4.616	4.627	4.638	4.649	4.660
.62..	4.671	4.682	4.693	4.704	4.715	4.726	4.737	4.748	4.759	4.770
.63..	4.781	4.792	4.803	4.814	4.825	4.836	4.848	4.859	4.870	4.881
.64..	4.892	4.903	4.914	4.925	4.936	4.947	4.959	4.970	4.981	4.992
.65..	5.003	5.014	5.025	5.036	5.047	5.058	5.070	5.081	5.092	5.103
.66..	5.114	5.125	5.137	5.148	5.160	5.171	5.182	5.194	5.205	5.216
.67..	5.228	5.239	5.251	5.262	5.274	5.285	5.296	5.308	5.319	5.330
.68..	5.342	5.353	5.365	5.376	5.388	5.399	5.410	5.422	5.433	5.446
.69..	5.456	5.467	5.479	5.490	5.502	5.513	5.525	5.536	5.548	5.559
.70..	5.571	5.583	5.594	5.606	5.617	5.629	5.641	5.652	5.664	5.675
.71..	5.687	5.699	5.710	5.722	5.733	5.745	5.757	5.768	5.780	5.791
.72..	5.803	5.815	5.826	5.838	5.850	5.861	5.873	5.885	5.897	5.908
.73..	5.920	5.932	5.944	5.955	5.967	5.979	5.991	6.003	6.014	6.026
.74..	6.038	6.050	6.062	6.073	6.085	6.097	6.109	6.121	6.132	6.144
.75..	6.156	6.168	6.180	6.192	6.204	6.215	6.227	6.239	6.251	6.263

TABLE III.—(Continued.)

4-Ft. Weir.

Head in ft.	0	1	2	3	4	5	6	7	8	9
.01..	.013	.015	.018	.020	.025	.025	.028	.030	.033	.035
.02..	.038	.041	.045	.048	.051	.054	.058	.061	.064	.068
.03..	.071	.075	.079	.082	.086	.090	.094	.098	.100	.105
.04..	.109	.113	.118	.122	.126	.130	.135	.139	.143	.148
.05..	.152	.157	.161	.166	.171	.175	.180	.185	.190	.194
.06..	.199	.204	.209	.215	.220	.225	.230	.235	.240	.246
.07..	.251	.256	.262	.267	.273	.278	.284	.289	.295	.300
.08..	.306	.312	.318	.324	.330	.335	.341	.347	.353	.359
.09..	.365	.371	.377	.384	.390	.396	.402	.408	.415	.421
.10..	.427	.433	.440	.446	.453	.459	.466	.472	.479	.485
.11..	.492	.499	.506	.512	.519	.526	.533	.540	.546	.553
.12..	.560	.567	.574	.582	.589	.596	.603	.610	.618	.625
.13..	.632	.639	.646	.654	.661	.668	.675	.682	.690	.697
.14..	.704	.712	.719	.727	.734	.742	.750	.757	.765	.772
.15..	.780	.788	.796	.803	.811	.819	.827	.835	.842	.850
.16..	.858	.866	.874	.882	.890	.898	.907	.915	.923	.931
.17..	.939	.947	.956	.964	.972	.980	.989	.997	1.005	1.014
.18..	1.022	1.030	1.039	1.047	1.056	1.064	1.073	1.081	1.090	1.098
.19..	1.107	1.116	1.124	1.133	1.142	1.150	1.159	1.168	1.177	1.185
.20..	1.194	1.203	1.212	1.221	1.230	1.239	1.248	1.257	1.266	1.275
.21..	1.284	1.293	1.302	1.311	1.320	1.329	1.339	1.348	1.357	1.366
.22..	1.375	1.484	1.494	1.503	1.512	1.521	1.532	1.540	1.549	1.559
.23..	1.468	1.477	1.487	1.496	1.506	1.515	1.525	1.534	1.544	1.553
.24..	1.563	1.573	1.582	1.592	1.602	1.611	1.621	1.631	1.641	1.650
.25..	1.660	1.670	1.680	1.690	1.700	1.709	1.719	1.729	1.739	1.748
.26..	1.759	1.769	1.779	1.789	1.799	1.809	1.819	1.729	1.839	1.849
.27..	1.859	1.869	1.879	1.889	1.900	1.910	1.920	1.930	1.941	1.951
.28..	1.961	1.971	1.982	1.992	2.003	2.013	2.023	2.034	2.044	2.055
.29..	2.065	2.075	2.086	2.096	2.107	2.117	2.128	2.138	2.149	2.159
.30..	2.170	2.181	2.191	2.202	2.213	2.223	2.234	2.245	2.256	2.266
.31..	2.277	2.288	2.299	2.309	2.320	2.331	2.342	2.353	2.363	2.374
.32..	2.385	2.396	2.407	2.418	2.429	2.240	2.451	2.462	2.473	2.484
.33..	2.495	2.506	2.517	2.529	2.540	2.551	2.562	2.573	2.584	2.596
.34..	2.607	2.618	2.630	2.641	2.652	2.663	2.675	2.686	2.697	2.709
.35..	2.720	2.731	2.743	2.754	2.766	2.777	2.788	2.800	2.811	2.823
.36..	2.834	2.845	2.857	2.868	2.880	2.891	2.903	2.914	2.926	2.937
.37..	2.949	2.961	2.972	2.984	2.996	3.007	3.019	3.031	3.043	3.054
.38..	3.066	3.078	3.090	3.101	3.113	3.125	3.137	3.149	3.160	3.172
.39..	3.184	3.196	3.208	3.220	3.232	3.244	3.256	3.268	3.280	3.292
.40..	3.304	3.316	3.328	3.341	3.353	3.365	3.377	3.389	3.402	3.414
.41..	3.426	3.438	3.450	3.463	3.475	3.487	3.500	3.512	3.524	3.537
.42..	3.549	3.561	3.574	3.586	3.599	3.611	3.623	3.636	3.649	3.661
.43..	3.674	3.687	3.699	3.712	3.725	3.737	3.750	3.763	3.776	3.788
.44..	3.801	3.814	3.827	3.839	3.852	3.865	3.878	3.891	3.903	3.916
.45..	3.929	3.942	3.955	3.968	3.981	3.993	4.006	4.019	4.032	4.045
.46..	4.058	4.071	4.084	4.098	4.111	4.124	4.136	4.150	4.164	4.177
.47..	4.190	4.203	4.216	4.230	4.243	4.256	4.269	4.282	4.296	4.309
.48..	4.322	4.335	4.348	4.362	4.375	4.388	4.402	4.415	4.428	4.442

Head in ft.	0	1	2	3	4	5	6	7	8	9
.49..	4.455	4.468	4.482	4.495	4.509	4.522	4.535	4.549	4.562	4.576
.50..	4.589	4.603	4.616	4.630	4.643	4.657	4.676	4.684	4.698	4.711
.51..	4.725	4.739	4.752	4.766	4.780	4.793	4.807	4.821	4.835	4.848
.52..	4.862	4.876	4.890	4.903	4.917	4.931	4.945	4.959	4.972	4.986
.53..	5.000	5.014	5.028	5.042	5.056	5.069	5.083	5.097	5.111	5.125
.54..	5.139	5.053	5.167	5.181	5.195	5.209	5.223	5.237	5.251	5.265
.55..	5.279	5.293	5.307	5.322	5.336	5.350	5.364	5.378	5.393	5.407
.56..	5.421	5.435	5.450	5.464	5.478	5.492	5.507	5.521	5.535	5.507
.57..	5.564	5.578	5.593	5.607	5.622	5.636	5.650	5.665	5.679	5.694
.58..	5.708	5.722	5.737	5.751	5.766	5.780	5.795	5.810	5.824	5.839
.59..	5.853	5.868	5.882	5.897	5.911	5.926	5.941	5.955	5.970	5.984
.60..	5.999	6.014	6.029	6.043	6.058	6.073	6.088	6.103	6.117	6.132
.61..	6.145	6.160	6.175	6.189	6.204	6.219	6.234	6.249	6.263	6.278
.62..	6.293	6.308	6.325	6.338	6.353	6.368	6.383	6.398	6.413	6.428
.63..	6.443	6.458	6.473	6.488	6.503	6.519	6.534	6.549	6.564	6.579
.64..	6.594	6.609	6.624	6.640	6.655	6.670	6.685	6.700	6.716	6.731
.65..	6.746	6.761	6.777	6.792	6.807	6.822	6.838	6.853	6.868	6.884
.66..	6.899	6.914	6.930	6.945	6.960	6.975	6.991	7.006	7.021	7.037
.67..	7.052	7.067	7.083	7.098	7.114	7.129	7.145	7.160	7.176	7.191
.68..	7.207	7.222	7.238	7.253	7.269	7.284	7.300	7.315	7.331	7.346
.69..	7.362	7.378	7.393	7.409	7.424	7.440	7.455	7.471	7.497	7.502
.70..	7.518	7.534	7.550	7.565	7.581	7.597	7.613	7.629	7.644	7.660
.71..	7.676	7.692	7.708	7.724	7.740	7.755	7.771	7.787	7.803	7.819
.72..	7.835	7.851	7.867	7.883	7.899	7.914	7.930	7.946	7.962	7.978
.73..	7.994	8.010	8.026	8.042	8.058	8.074	8.090	8.106	8.122	8.138
.74..	8.154	8.170	8.186	8.202	8.218	8.234	8.251	8.267	8.283	8.299
.75..	8.315	8.331	8.348	8.365	8.380	8.396	8.413	8.429	8.445	8.462
.76..	8.478	8.494	8.511	8.527	8.543	8.559	8.576	8.592	8.608	8.625
.77..	8.641	8.657	8.674	8.690	8.706	8.723	8.739	8.756	8.772	8.788
.78..	8.805	8.821	8.839	8.854	8.871	8.887	8.904	8.920	8.937	8.953
.79..	8.970	8.987	9.003	9.020	9.036	9.053	9.070	9.086	9.103	9.119
.80..	9.136	9.153	9.169	9.186	9.202	9.219	9.236	9.252	9.269	9.285
.81..	9.302	9.319	9.336	9.352	9.369	9.386	9.403	9.420	9.436	9.453
.82..	9.470	9.487	9.504	9.520	9.538	9.554	9.571	9.588	9.605	9.622
.83..	9.639	9.656	9.673	9.690	9.707	9.723	9.740	9.757	9.774	9.791
.84..	9.808	9.825	9.842	9.859	9.876	9.893	9.910	9.927	9.944	9.961
.85..	9.978	9.995	10.012	10.029	10.046	10.063	10.081	10.098	10.115	10.132
.86..	10.149	10.166	10.184	10.201	10.218	10.235	10.253	10.270	10.287	10.304
.87..	10.322	10.339	10.356	10.374	10.391	10.408	10.426	10.443	10.460	10.477
.88..	10.495	10.512	10.530	10.547	10.563	10.581	10.599	10.616	10.633	10.651
.89..	10.668	10.685	10.703	10.719	10.737	10.754	10.771	10.789	10.806	10.824
.90..	10.841	10.858	10.876	10.893	10.911	10.923	10.946	10.963	10.981	10.998
.91..	11.016	11.034	11.051	11.069	11.086	11.104	11.122	11.139	11.157	11.174
.92..	11.192	11.210	11.227	11.245	11.263	11.280	11.298	11.316	11.334	11.351
.93..	11.369	11.787	11.404	11.422	11.440	11.457	11.475	11.493	11.511	11.528
.94..	11.546	11.564	11.582	11.600	11.617	11.635	11.653	11.671	11.689	11.707
.95..	11.725	11.743	11.761	11.779	11.797	11.814	11.832	11.850	11.868	11.886
.96..	11.904	11.922	11.940	11.958	11.976	11.994	12.012	12.030	12.048	12.066
.97..	12.084	12.102	12.120	12.138	12.156	12.174	12.192	12.210	12.228	12.246
.98..	12.264	12.282	12.300	12.318	12.336	12.354	12.372	12.391	12.409	12.427
.99..	12.445	12.463	12.482	12.500	12.518	12.536	12.554	12.572	12.591	12.608
1.00..	12.627	12.645	12.663	12.682	12.700	12.718	12.736	12.754	12.773	12.791

TABLE III.—(Continued.)

5-Ft. Weir.

Head in ft.	0	1	2	3	4	5	6	7	8	9
.01..	.017	.020	.023	.026	.029	.032	.036	.039	.042	.045
.02..	.048	.052	.056	.060	.064	.068	.072	.076	.080	.084
.03..	.088	.093	.098	.102	.107	.112	.117	.122	.126	.131
.04..	.136	.141	.147	.152	.158	.163	.168	.174	.179	.185
.05..	.190	.196	.202	.208	.214	.219	.225	.231	.237	.243
.06..	.249	.255	.262	.268	.275	.281	.288	.294	.301	.307
.07..	.314	.321	.328	.335	.342	.348	.355	.362	.369	.376
.08..	.383	.390	.398	.405	.413	.420	.427	.435	.442	.450
.09..	.457	.464	.472	.480	.487	.495	.502	.510	.518	.525
.10..	.534	.542	.550	.558	.566	.574	.583	.591	.599	.607
.11..	.615	.624	.632	.641	.649	.658	.667	.675	.684	.692
.12..	.701	.710	.718	.727	.736	.745	.754	.762	.771	.780
.13..	.789	.798	.807	.817	.826	.835	.844	.853	.863	.872
.14..	.881	.890	.900	.909	.919	.928	.938	.947	.957	.966
.15..	.976	.986	.996	1.006	1.016	1.025	1.035	1.045	1.055	1.065
.16..	1.075	1.085	1.095	1.105	1.115	1.125	1.136	1.146	1.156	1.166
.17..	1.176	1.186	1.197	1.207	1.218	1.228	1.238	1.249	1.259	1.270
.18..	1.280	1.291	1.301	1.312	1.322	1.333	1.344	1.354	1.365	1.375
.19..	1.386	1.397	1.408	1.419	1.430	1.441	1.452	1.463	1.474	1.485
.20..	1.496	1.507	1.518	1.530	1.541	1.552	1.563	1.574	1.586	1.597
.21..	1.608	1.619	1.631	1.642	1.653	1.665	1.676	1.688	1.699	1.711
.22..	1.722	1.734	1.745	1.757	1.769	1.780	1.792	1.804	1.816	1.827
.23..	1.839	1.851	1.863	1.875	1.887	1.899	1.911	1.923	1.935	1.947
.24..	1.959	1.971	1.983	1.995	2.007	2.019	2.032	2.044	2.056	2.068
.25..	2.080	2.092	2.105	2.117	2.130	2.142	2.154	2.167	2.179	2.192
.26..	2.204	2.217	2.229	2.242	2.254	2.267	2.280	2.292	2.305	2.317
.27..	2.330	2.343	2.356	2.368	2.381	2.394	2.407	2.420	2.432	2.445
.28..	2.458	2.471	2.484	2.497	2.510	2.523	2.536	2.549	2.562	2.575
.29..	2.588	2.601	2.615	2.628	2.641	2.654	2.668	2.681	2.694	2.708
.30..	2.721	2.734	2.748	2.761	2.775	2.788	2.801	2.815	2.828	2.841
.31..	2.855	2.869	2.822	2.896	2.909	2.923	2.937	2.950	2.964	2.977
.32..	2.991	3.005	3.019	3.033	3.047	3.060	3.074	3.088	3.102	3.116
.33..	3.130	3.144	3.158	3.172	3.186	3.200	3.214	3.228	3.242	3.256
.34..	3.270	3.284	3.298	3.313	3.327	3.341	3.355	3.369	3.384	3.398
.35..	3.412	3.426	3.441	3.455	3.469	3.483	3.498	3.512	3.526	3.541
.36..	3.555	3.570	3.584	3.599	3.613	3.628	3.643	3.657	3.672	3.686
.37..	3.701	3.716	3.730	3.746	3.760	3.774	3.789	3.804	3.819	3.833
.38..	3.848	3.863	3.878	3.893	3.908	3.922	3.937	3.952	3.967	3.982
.39..	3.997	4.012	4.027	4.042	4.057	4.072	4.087	4.102	4.117	4.132
.40..	4.147	4.162	4.178	4.193	4.208	4.223	4.239	4.254	4.269	4.285
.41..	4.300	4.315	4.331	4.346	4.362	4.377	4.393	4.408	4.424	4.439
.42..	4.455	4.471	4.486	4.502	4.518	4.534	4.550	4.565	4.581	4.597
.43..	4.613	4.629	4.645	4.661	4.677	4.693	4.709	4.725	4.741	4.757
.44..	4.773	4.789	4.805	4.822	4.838	4.854	4.870	4.886	4.902	4.919
.45..	4.935	4.951	4.967	4.984	5.000	5.016	5.032	5.048	5.065	5.081
.46..	5.097	5.113	5.130	5.146	5.163	5.179	5.196	5.212	5.229	5.245
.47..	5.262	5.279	5.295	5.312	5.329	5.345	5.362	5.379	5.396	5.412
.48..	5.429	5.446	5.463	5.479	5.496	5.513	5.530	5.547	5.563	5.580
.49..	5.597	5.616	5.631	5.649	5.665	5.682	5.699	5.716	5.733	5.750
.50..	5.767	5.784	5.801	5.818	5.835	5.852	5.869	5.886	5.903	5.920
.51..	5.937	5.954	5.971	5.989	6.006	6.023	6.040	6.057	6.075	6.092
.52..	6.109	6.126	6.144	6.161	6.179	6.196	6.213	6.231	6.248	6.266
.53..	6.283	6.301	6.318	6.336	6.353	6.371	6.389	6.406	6.424	6.441
.54..	6.459	6.477	6.495	6.512	6.530	6.548	6.566	6.584	6.601	6.619
.55..	6.637	6.655	6.673	6.691	6.709	6.726	6.744	6.762	6.780	6.789
.56..	6.816	6.834	6.852	6.870	6.888	6.906	6.924	6.942	6.960	6.978
.57..	6.996	7.014	7.032	7.051	7.069	7.087	7.105	7.123	7.142	7.160
.58..	7.178	7.196	7.215	7.233	7.251	7.269	7.288	7.306	7.324	7.342
.59..	7.361	7.379	7.398	7.416	7.435	7.452	7.472	7.490	7.509	7.527
.60..	7.546	7.565	7.583	7.602	7.620	7.639	7.658	7.676	7.695	7.713
.61..	7.732	7.751	7.769	7.788	7.807	7.825	7.844	7.863	7.882	7.900
.62..	7.919	7.938	7.957	7.976	7.995	8.013	8.032	8.051	8.070	8.089
.63..	8.108	8.127	8.146	8.165	8.184	8.203	8.222	8.241	8.260	8.279
.64..	8.298	8.317	8.336	8.355	8.375	8.394	8.413	8.432	8.452	8.471
.65..	8.490	8.509	8.528	8.548	8.567	8.586	8.605	8.624	8.644	8.663
.66..	8.682	8.701	8.721	8.740	8.760	8.779	8.798	8.818	8.837	8.857
.67..	8.876	8.896	8.915	8.935	8.954	8.974	8.994	9.013	9.033	9.052
.68..	9.072	9.092	9.111	9.131	9.151	9.170	9.190	9.209	9.230	9.249
.69..	9.269	9.289	9.309	9.328	9.348	9.368	9.388	9.408	9.427	9.447
.70..	9.467	9.487	9.507	9.527	9.547	9.566	9.586	9.606	9.627	9.647
.71..	9.666	9.686	9.706	9.726	9.746	9.766	9.786	9.806	9.826	9.846
.72..	9.867	9.887	9.907	9.927	9.947	9.967	9.987	10.007	10.027	10.047
.73..	10.068	10.088	10.108	10.129	10.149	10.169	10.190	10.210	10.230	10.251
.74..	10.271	10.291	10.312	10.332	10.353	10.373	10.393	10.414	10.437	10.455
.75..	10.475	10.496	10.516	10.537	10.557	10.578	10.598	10.619	10.640	10.660
.76..	10.681	10.702	10.722	10.743	10.764	10.784	10.805	10.826	10.846	10.867

Head in ft.	0	1	2	3	4	5	6	7	8	9
.77..	10.888	10.909	10.930	10.950	10.971	10.992	11.013	11.034	11.054	11.075
.78..	11.096	11.117	11.138	11.159	11.180	11.200	11.221	11.242	11.263	11.284
.79..	11.305	11.326	11.347	11.368	11.389	11.410	11.431	11.452	11.473	11.494
.80..	11.515	11.536	11.557	11.578	11.599	11.620	11.642	11.663	11.684	11.705
.81..	11.726	11.747	11.769	11.790	11.811	11.832	11.854	11.875	11.896	11.918
.82..	11.939	11.960	11.982	12.003	12.025	12.046	12.067	12.089	12.110	12.131
.83..	12.153	12.174	12.196	12.217	12.239	12.260	12.281	12.303	12.324	12.345
.84..	12.367	12.389	12.410	12.432	12.453	12.475	12.497	12.518	12.540	12.561
.85..	12.583	12.605	12.627	12.648	12.670	12.692	12.714	12.736	12.757	12.779
.86..	12.801	12.823	12.845	12.866	12.888	12.910	12.932	12.954	12.975	12.997
.87..	13.019	13.041	13.063	13.085	13.107	13.128	13.150	13.172	13.194	13.216
.88..	13.238	13.260	13.282	13.304	13.326	13.348	13.371	13.393	13.415	13.437
.89..	13.459	13.481	13.503	13.525	13.547	13.569	13.592	13.614	13.636	13.658
.90..	13.680	13.702	13.725	13.747	13.769	13.791	13.814	13.836	13.858	13.881
.91..	13.903	13.925	13.948	13.970	13.992	14.014	14.037	14.059	14.081	14.014
.92..	14.126	14.148	14.171	14.193	14.216	14.238	14.261	14.283	14.306	14.328
.93..	14.351	14.373	14.396	14.418	14.441	14.463	14.486	14.508	14.531	14.553
.94..	14.576	14.599	14.621	14.644	14.666	14.689	14.712	14.734	14.757	14.779
.95..	14.802	14.825	14.847	14.870	14.893	14.915	14.938	14.961	14.984	15.006
.96..	15.029	15.052	15.075	15.098	15.121	15.143	15.166	15.189	15.212	15.235
.97..	15.258	15.281	15.304	15.327	15.350	15.373	15.396	15.419	15.442	15.465
.98..	15.488	15.511	15.534	15.557	15.580	15.603	15.626	15.649	15.672	15.695
.99..	15.718	15.741	15.764	15.787	15.811	15.834	15.857	15.880	15.904	15.927
1.00..	15.950	15.973	15.996	16.019	16.043	16.066	16.089	16.112	16.136	16.159
1.01..	16.182	16.205	16.229	16.252	16.276	16.299	16.322	16.346	16.369	16.392
1.02..	16.416	16.439	16.463	16.486	16.510	16.533	16.557	16.580	16.604	16.627
1.03..	16.651	16.675	16.698	16.722	16.745	16.769	16.792	16.816	16.840	16.863
1.04..	16.887	16.911	16.934	16.958	16.982	17.005	17.029	17.053	17.077	17.100
1.05..	17.124	17.148	17.171	17.195	17.219	17.242	17.266	17.290	17.314	17.337
1.06..	17.361	17.386	17.409	17.432	17.456	17.479	17.503	17.527	17.551	17.574
1.07..	17.599	17.623	17.647	17.671	17.694	17.718	17.742	17.766	17.790	17.814
1.08..	17.838	17.862	17.886	17.910	17.934	17.958	17.982	18.006	18.030	18.054
1.09..	18.078	18.102	18.126	18.150	18.174	18.198	18.223	18.247	18.271	18.295
1.10..	18.319	18.343	18.368	18.392	18.416	18.440	18.465	18.489	18.513	18.537
1.11..	18.562	18.586	18.610	18.635	18.659	18.683	18.708	18.732	18.756	18.781
1.12..	18.805	18.829	18.854	18.878	18.903	18.927	18.951	18.976	19.000	19.025
1.13..	19.049	19.073	19.098	19.122	19.147	19.171	19.196	19.220	19.245	19.269
1.14..	19.294	19.318	19.343	19.367	19.392	19.416	19.441	19.465	19.490	19.514
1.15..	19.539	19.564	19.588	19.613	19.637	19.662	19.687	19.711	19.736	19.760
1.16..	19.785	19.810	19.835	19.859	19.884	19.909	19.934	19.959	19.983	20.008
1.17..	20.033	20.058	20.083	20.107	20.132	20.157	20.182	20.207	20.231	20.259
1.18..	20.281	20.306	20.331	20.356	20.381	20.405	20.430	20.455	20.480	20.505
1.19..	20.530	20.555	20.580	20.605	20.630	20.655	20.680	20.705	20.730	20.755
1.20..	20.780	20.805	20.830	20.855	20.880	20.905	20.931	20.956	20.981	21.006
1.21..	21.031	21.056	21.081	21.106	21.132	21.157	21.182	21.207	21.233	21.258
1.22..	21.283	21.308	21.333	21.359	21.384	21.409	21.434	21.459	21.485	21.510
1.23..	21.535	21.560	21.585	21.611	21.637	21.663	21.687	21.713	21.738	21.764
1.24..	21.789	21.814	21.840	21.865	21.891	21.916	21.941	21.967	21.992	22.017
1.25..	22.043	22.068	22.094	22.119	22.145	22.170	22.196	22.221	22.247	22.272

TABLE III.—(Continued.)

6-Ft. Weir.

Head in ft.	0	1	2	3	4	5	6	7	8	9
.01..	.021	.025	.028	.032	.036	.039	.043	.047	.051	.054
.02..	.058	.063	.067	.072	.077	.082	.087	.092	.096	.101
.03..	.106	.112	.117	.123	.129	.134	.140	.146	.152	.157
.04..	.163	.169	.176	.182	.189	.195	.202	.208	.215	.221
.05..	.228	.235	.242	.249	.256	.263	.271	.278	.285	.292
.06..	.299	.307	.315	.322	.330	.338	.346	.354	.361	.369
.07..	.377	.385	.394	.402	.410	.418	.427	.435	.443	.452
.08..	.460	.469	.478	.486	.495	.504	.513	.522	.530	.539
.09..	.548	.557	.567	.576	.585	.594	.604	.613	.622	.632
.10..	.641	.651	.660	.670	.680	.689	.699	.709	.719	.728
.11..	.738	.748	.759	.769	.780	.790	.800	.811	.821	.832
.12..	.842	.853	.863	.874	.885	.895	.906	.917	.928	.938
.13..	.949	.960	.971	.982	.993	1.004	1.015	1.026	1.037	1.048
.14..	1.059	1.070	1.082	1.093	1.105	1.116	1.127	1.139	1.150	1.162
.15..	1.173	1.185	1.197	1.208	1.220	1.232	1.244	1.256	1.267	1.279
.16..	1.291	1.303	1.315	1.327	1.339	1.351	1.364	1.376	1.388	1.400
.17..	1.412	1.425	1.437	1.450	1.462	1.475	1.488	1.500	1.513	1.525
.18..	1.538	1.551	1.564	1.576	1.589	1.602	1.615	1.628	1.640	1.653
.19..	1.666	1.679	1.692	1.706	1.719	1.732	1.745	1.758	1.772	1.785
.20..	1.798	1.811	1.825	1.838	1.852	1.865	1.878	1.892	1.905	1.919
.21..	1.932	1.946	1.960	1.974	1.988	2.002	2.016	2.029	2.042	2.056
.22..	2.070	2.084	2.098	2.112	2.126	2.140	2.154	2.168	2.182	2.196
.23..	2.210	2.224	2.239	2.253	2.268	2.282	2.296	2.311	2.325	2.340
.24..	2.354	2.369	2.383	2.398	2.412	2.427	2.442	2.456	2.471	2.485
.25..	2.500	2.515	2.530	2.544	2.559	2.574	2.589	2.604	2.628	2.643
.26..	2.648	2.663	2.679	2.694	2.709	2.724	2.740	2.755	2.770	2.785
.27..	2.801	2.816	2.832	2.847	2.863	2.878	2.893	2.909	2.924	2.940
.28..	2.955	2.971	2.986	3.002	3.018	3.033	3.049	3.065	3.081	3.096
.29..	3.112	3.128	3.144	3.160	3.176	3.191	3.207	3.223	3.239	3.255
.30..	3.271	3.287	3.303	3.320	3.336	3.352	3.368	3.384	3.401	3.417
.31..	3.433	3.449	3.466	3.482	3.499	3.515	3.531	3.548	3.564	3.581
.32..	3.597	3.614	3.630	3.647	3.664	3.680	3.697	3.714	3.731	3.747
.33..	3.764	3.781	3.798	3.815	3.832	3.849	3.866	3.883	3.900	3.917
.34..	3.934	3.951	3.968	3.986	4.003	4.020	4.037	4.054	4.072	4.089
.35..	4.106	4.123	4.141	4.158	4.175	4.192	4.210	4.227	4.244	4.262
.36..	4.279	4.296	4.314	4.331	4.349	4.366	4.383	4.401	4.418	4.436
.37..	4.453	4.471	4.488	4.506	4.523	4.541	4.559	4.576	4.594	4.611
.38..	4.629	4.647	4.665	4.683	4.701	4.719	4.737	4.755	4.773	4.791
.39..	4.809	4.827	4.845	4.863	4.881	4.899	4.918	4.936	4.954	4.972
.40..	4.990	5.008	5.027	5.045	5.064	5.082	5.100	5.119	5.137	5.156
.41..	5.174	5.193	5.212	5.230	5.249	5.268	5.286	5.304	5.322	5.340
.42..	5.362	5.381	5.400	5.419	5.438	5.457	5.476	5.495	5.514	5.533
.43..	5.552	5.571	5.591	5.610	5.629	5.649	5.668	5.687	5.706	5.726
.44..	5.745	5.764	5.784	5.803	5.823	5.842	5.862	5.881	5.901	5.920
.45..	5.940	5.960	5.979	5.999	6.018	6.038	6.058	6.077	6.079	6.116
.46..	6.136	6.156	6.176	6.196	6.216	6.235	6.255	6.275	6.295	6.315
.47..	6.335	6.355	6.375	6.395	6.415	6.435	6.456	6.476	6.496	6.516
.48..	6.536	6.556	6.576	6.597	6.616	6.637	6.657	6.677	6.698	6.718
.49..	6.739	6.758	6.778	6.799	6.819	6.839	6.860	6.880	6.900	6.921
.50..	6.941	6.961	6.982	7.002	7.023	7.043	7.064	7.084	7.105	7.125
.51..	7.146	7.167	7.188	7.208	7.229	7.250	7.271	7.292	7.312	7.333
.52..	7.354	7.375	7.396	7.417	7.438	7.459	7.480	7.501	7.522	7.543
.53..	7.564	7.585	7.607	7.628	7.650	7.671	7.692	7.714	7.735	7.757
.54..	7.778	7.800	7.821	7.843	7.864	7.886	7.908	7.929	7.951	7.972
.55..	7.994	8.016	8.037	8.059	8.080	8.102	8.124	8.145	8.167	8.188
.56..	8.210	8.232	8.254	8.275	8.297	8.319	8.341	8.363	8.384	8.406
.57..	8.428	8.450	8.472	8.494	8.516	8.538	8.560	8.582	8.604	8.626
.58..	8.648	8.670	8.692	8.714	8.736	8.758	8.781	8.803	8.825	8.847
.59..	8.869	8.891	8.914	8.936	8.958	8.980	9.003	9.025	9.047	9.070
.60..	9.092	9.114	9.137	9.159	9.182	9.204	9.227	9.249	9.272	9.294
.61..	9.317	9.340	9.362	9.385	9.407	9.430	9.453	9.475	9.498	9.520
.62..	9.543	9.566	9.589	9.611	9.634	9.657	9.680	9.703	9.725	9.748
.63..	9.771	9.794	9.817	9.840	9.863	9.886	9.909	9.932	9.955	9.978
.64..	10

Head in ft.	0	1	2	3	4	5	6	7	8	9
.79	13.640	13.665	13.691	13.716	13.742	13.767	13.793	13.818	13.844	13.869
.80	13.895	13.920	13.946	13.971	13.997	14.022	14.048	14.073	14.099	14.124
.81	14.150	14.176	14.202	14.227	14.253	14.279	14.305	14.331	14.356	14.382
.82	14.408	14.434	14.460	14.486	14.512	14.537	14.563	14.589	14.615	14.641
.83	14.667	14.693	14.719	14.745	14.771	14.797	14.823	14.849	14.875	14.901
.84	14.927	14.953	14.979	15.006	15.032	15.058	15.084	15.110	15.137	15.163
.85	15.189	15.215	15.242	15.268	15.294	15.320	15.347	15.373	15.399	15.426
.86	15.452	15.478	15.505	15.531	15.558	15.584	15.610	15.637	15.663	15.690
.87	15.716	15.743	15.769	15.796	15.823	15.849	15.876	15.903	15.930	15.956
.88	15.983	16.010	16.036	16.063	16.090	16.116	16.143	16.170	16.197	16.223
.89	16.250	16.277	16.304	16.330	16.357	16.384	16.411	16.438	16.464	16.491
.90	16.518	16.545	16.572	16.599	16.626	16.652	16.679	16.706	16.733	16.760
.91	16.787	16.814	16.841	16.868	16.895	16.922	16.950	16.978	17.004	17.031
.92	17.058	17.085	17.112	17.140	17.167	17.194	17.221	17.248	17.276	17.303
.93	17.330	17.357	17.385	17.412	17.440	17.467	17.495	17.522	17.550	17.577
.94	17.605	17.632	17.660	17.687	17.715	17.742	17.770	17.797	17.825	17.852
.95	17.880	17.908	17.935	17.963	17.990	18.018	18.046	18.073	18.102	18.128
.96	18.156	18.184	18.212	18.239	18.267	18.295	18.323	18.351	18.378	18.406
.97	18.434	18.462	18.490	18.518	18.546	18.573	18.601	18.629	18.657	18.685
.98	18.713	18.741	18.769	18.797	18.825	18.852	18.880	18.908	18.936	18.964
.99	18.992	19.020	19.048	19.076	19.104	19.132	19.161	19.189	19.217	19.245
1.00	19.273	19.301	19.329	19.358	19.386	19.414	19.442	19.470	19.499	19.527
1.01	19.555	19.583	19.612	19.640	19.669	19.697	19.725	19.754	19.782	19.811
1.02	19.839	19.867	19.896	19.924	19.953	19.981	20.010	20.038	20.067	20.095
1.03	20.124	20.153	20.181	20.210	20.238	20.267	20.296	20.324	20.353	20.381
1.04	20.410	20.439	20.468	20.496	20.525	20.554	20.583	20.612	20.640	20.669
1.05	20.698	20.727	20.756	20.784	20.814	20.842	20.871	20.900	20.929	20.958
1.06	20.987	21.016	21.045	21.074	21.103	21.131	21.160	21.189	21.218	21.247
1.07	21.276	21.305	21.334	21.363	21.392	21.421	21.451	21.480	21.509	21.538
1.08	21.567	21.596	21.625	21.654	21.684	21.713	21.742	21.771	21.801	21.830
1.09	21.859	21.888	21.918	21.947	21.976	22.005	22.035	22.064	22.093	22.123
1.10	22.152	22.181	22.211	22.240	22.270	22.300	22.329	22.358	22.388	22.417
1.11	22.447	22.476	22.506	22.535	22.565	22.594	22.624	22.653	22.683	22.712
1.12	22.742	22.772	22.801	22.831	22.860	22.890	22.920	22.949	22.979	23.008
1.13	23.038	23.068	23.098	23.127	23.157	23.187	23.217	23.247	23.276	23.306
1.14	23.336	23.366	23.396	23.426	23.456	23.485	23.515	23.545	23.575	23.605
1.15	23.635	23.665	23.695	23.725	23.755	23.785	23.815	23.845	23.875	23.905
1.16	23.935	23.965	23.995	24.025	24.055	24.085	24.116	24.146	24.176	24.206
1.17	24.236	24.266	24.296	24.327	24.357	24.387	24.417	24.447	24.478	24.508
1.18	24.538	24.568	24.599	24.629	24.660	24.690	24.720	24.751	24.781	24.812
1.19	24.842	24.872	24.903	24.933	24.964	24.994	25.024	25.055	25.085	25.116
1.20	25.146	25.176	25.207	25.237	25.268	25.298	25.329	25.359	25.390	25.420
1.21	24.451	25.482	25.512	25.543	25.573	25.604	25.635	25.665	25.696	25.726
1.22	25.757	25.788	25.819	25.849	25.880	25.911	25.942	25.973	26.003	26.034
1.23	26.065	26.096	26.127	26.157	26.188	26.219	26.250	26.281	26.311	26.342
1.24	26.373	26.404	26.435	26.466	26.491	26.528	26.559	26.590	26.621	26.652
1.25	26.683	26.714	26.745	26.776	26.807	26.838	26.869	26.900	26.931	26.962
1.26	26.993	27.024	27.055	27.087	27.118	27.149	27.180	27.211	27.243	27.274
1.27	27.305	27.336	27.368	27.399	27.430	27.461	27.493	27.524	27.555	27.587
1.28	27.618	27.649	27.681	27.712	27.744	27.775	27.806	27.838	27.869	27.901
1.29	27.932	27.963	27.995	28.026	28.058	28.089	28.121	28.152	28.184	28.215
1.30	28.247	28.278	28.310	28.341	28.373	28.404	28.436	28.467	28.499	28.530
1.31	28.562	28.594	28.625	28.657	28.689	28.720	28.752	28.784	28.816	28.847
1.32	28.879	28.911	28.942	28.974	29.006	29.037	29.069	29.101	29.133	29.164
1.33	29.196	29.229	29.260	29.292	29.324	29.355	29.387	29.419	29.451	29.483
1.34	29.515	29.547	29.579	29.611	29.643	29.675	29.707	29.739	29.771	29.803
1.35	29.835	29.867	29.899	29.931	29.963	29.995	30.028	30.060	30.092	30.124
1.36	30.156	30.188	30.220	30.252	30.284	30.316	30.349	30.381	30.413	30.445
1.37	30.477	30.509	30.542	30.574	30.606	30.638	30.671	30.703	30.735	30.768
1.38	30.800	30.832	30.865	30.897	30.930	30.962	30.994	31.027	31.059	31.092
1.39	31.124	31.156	31.189	31.221	31.254	31.286	31.318	31.351	31.383	31.416
1.40	31.448	31.480	31.513	31.545	31.578	31.610	31.643	31.675	31.708	31.740
1.41	31.773	31.806	31.838	31.871	31.904	31.936	31.969	32.002	32.035	32.067
1.42	32.100	32.133	32.165	32.198	32.231	32.263	32.296	32.329	32.362	32.394
1.43	32.427	32.460	32.493	32.525	32.558	32.591	32.624	32.657	32.689	32.722
1.44	32.755	32.788	32.821	32.854	32.887	32.920	32.953	32.986	33.019	33.052
1.45	33.085	33.118	33.151	33.184	33.217	33.250	33.283	33.316	33.349	33.382
1.46	33.415	33.448	33.481	33.514	33.547	33.580	33.614	33.647	33.680	33.713
1.47	33.746	33.779	33.812	33.846	33.879	33.912	33.945	33.978	34.012	34.045
1.48	34.078	34.111	34.144	34.178	34.211	34.244	34.277	34.310	34.344	34.377
1.49	34.410	34.443	34.477	34.510	34.544	34.577	34.611	34.644	34.678	34.711
1.50	34.745	34.779	34.812	34.846	34.879	34.913	34.947	34.980	35.014	35.047

TABLE III.—(Continued.)

8-Ft. Weir.

Head in ft.	0	1	2	3	4	5.	6.	7.	8.	9.
.01	.024	.029	.035	.040	.045	.050	.056	.061	.066	.072
.02	.077	.083	.090	.096	.103	.109	.115	.122	.128	.135
.03	.141	.149	.156	.164	.172	.179	.187	.195	.203	.210
.04	.218	.226	.235	.243	.252	.260	.269	.277	.286	.294
.05	.303	.313	.322	.332	.341	.351	.361	.370	.380	.389
.06	.399	.409	.420	.430	.441	.451	.461	.472	.482	.493
.07	.503	.514	.525	.536	.547	.558	.569	.580	.591	.602
.08	.613	.625	.637	.648	.660	.672	.684	.696	.707	.719
.09	.731	.743	.756	.768	.781	.793	.806	.818	.831	.843
.10	.856	.869	.882	.895	.908	.921	.935	.948	.961	.974
.11	.987	1.001	1.014	1.028	1.041	1.055	1.069	1.082	1.096	1.109
.12	1.123	1.137	1.151	1.166	1.180	1.194	1.208	1.222	1.237	1.251
.13	1.265	1.280	1.295	1.309	1.324	1.339	1.354	1.369	1.383	1.398
.14	1.413	1.428	1.444	1.459	1.474	1.489	1.504	1.520	1.535	1.551
.15	1.566	1.582	1.597	1.613	1.629	1.644	1.660	1.676	1.692	1.707
.16	1.723	1.739	1.756	1.772	1.788	1.804	1.821	1.837	1.853	1.870
.17	1.886	1.903	1.919	1.936	1.953	1.969	1.986	2.003	2.020	2.036
.18	2.053	2.070	2.087	2.105	2.122	2.139	2.156	2.173	2.191	2.208
.19	2.225	2.243	2.260	2.278	2.295	2.313	2.331	2.348	2.366	2.383
.20	2.401	2.419	2.437	2.455	2.473	2.491	2.509	2.527	2.545	2.563
.21	2.581	2.599	2.618	2.636	2.655	2.673	2.691	2.710	2.728	2.747
.22	2.765	2.784	2.803	2.821	2.840	2.859	2.878	2.897	2.915	2.934
.23	2.953	2.972	2.991	3.011	3.030	3.049	3.068	3.087	3.107	3.126
.24	3.145	3.165	3.184	3.204	3.223	3.243	3.263	3.282	3.302	3.321
.25	3.341	3.361	3.381	3.401	3.421	3.440	3.460	3.480	3.500	3.520
.26	3.540	3.560	3.581	3.601	3.621	3.641	3.662	3.682	3.702	3.723
.27	3.743	3.764	3.784	3.805	3.825	3.846	3.867	3.887	3.908	3.928
.28	3.949	3.970	3.991	4.012	4.033	4.053	4.074	4.095	4.116	4.137
.29	4.158	4.179	4.200	4.222	4.243	4.264	4.285	4.306	4.328	4.349
.30	4.370	4.391	4.413	4.434	4.456	4.477	4.499	4.520	4.542	4.563
.31	4.585	4.607	4.629	4.650	4.672	4.694	4.716	4.738	4.759	4.781
.32	4.803	4.825	4.847	4.870	4.892	4.914	4.936	4.958	4.981	5.003
.33	5.025	5.048	5.070	5.093	5.115	5.138	5.161	5.183	5.206	5.228
.34	5.251	5.274	5.297	5.320	5.343	5.366	5.389	5.412	5.435	5.458
.35	5.481	5.504	5.528	5.551	5.575	5.598	5.621	5.645	5.668	5.692
.36	5.715	5.739	5.762	5.786	5.810	5.833	5.857	5.881	5.904	5.928
.37	5.952	5.976	6.000	6.024	6.048	6.072	6.096	6.120	6.144	6.168
.38	6.192	6.216	6.240	6.264	6.288	6.312	6.337	6.361	6.385	6.409
.39	6.433	6.457	6.482	6.506	6.531	6.555	6.579	6.604	6.628	6.653
.40	6.677	6.702	6.726	6.751	6.775	6.800	6.825	6.849	6.874	6.898
.41	6.923	6.948	6.973	6.999	7.024	7.049	7.074	7.099	7.125	7.150
.42	7.175	7.200	7.226	7.251	7.277	7.302	7.328	7.353	7.379	7.404
.43	7.430	7.456	7.482	7.507	7.533	7.559	7.585	7.611	7.636	7.662
.44	7.688	7.714	7.740	7.767	7.793	7.819	7.845	7.871	7.898	7.924
.45	7.950	7.976	8.003	8.029	8.056	8.082	8.108	8.135	8.161	8.188
.46	8.214	8.241	8.267	8.294	8.320	8.347	8.374	8.400	8.427	8.453
.47	8.480	8.507	8.534	8.561	8.588	8.615	8.642	8.669	8.696	8.723
.48	8.750	8.777	8.804	8.832	8.859	8.886	8.913	8.940	8.968	8.995
.49	9.022	9.049	9.077	9.104	9.132	9.159	9.187	9.214	9.242	9.269
.50	9.297	9.325	9.352	9.380	9.408	9.435	9.463	9.491	9.519	9.546
.51	9.574	9.602	9.630	9.658	9.686	9.713	9.741	9.769	9.797	9.825
.52	9.853	9.881	9.910	9.938	9.966	9.994	10.023	10.051	10.079	10.108
.53	10.136	10.164	10.193	10.221	10.250	10.278	10.307	10.335	10.364	10.392
.54	10.421	10.450	10.479	10.507	10.536	10.565	10.594	10.623	10.651	10.680
.55	10.709	10.738	10.767	10.796	10.825	10.854	10.883	10.912	10.941	10.970
.56	10.999	11.028	11.057	11.087	11.116	11.145	11.174	11.203	11.233	11.262

Head in ft.	0	1	2	3	4	5	6	7	8	9
.57	11.291	11.321	11.350	11.380	11.409	11.439	11.469	11.498	11.528	11.557
.58	11.587	11.617	11.646	11.676	11.706	11.735	11.765	11.795	11.825	11.854
.59	11.884	11.914	11.944	11.974	12.004	12.034	12.064	12.094	12.124	12.154
.60	12.184	12.214	12.245	12.275	12.305	12.335	12.366	12.396	12.426	12.456
.61	12.487	12.517	12.548	12.578	12.609	12.639	12.670	12.700	12.731	12.761
.62	12.792	12.823	12.853	12.884	12.915	12.945	12.976	13.007	13.038	13.068
.63	13.099	13.130	13.161	13.192	13.223	13.253	13.284	13.315	13.346	13.377
.64	13.408	13.439	13.470	13.501	13.532	13.563	13.595	13.625	13.657	13.688
.65	13.719	13.750	13.782	13.813	13.845	13.876	13.907	13.939	13.970	14.002
.66	14.033	14.065	14.096	14.128	14.159	14.191	14.223	14.254	14.286	14.317
.67	14.349	14.381	14.413	14.444	14.476	14.508	14.540	14.572	14.603	14.635
.68	14.667	14.699	14.731	14.763	14.795	14.827	14.860	14.892	14.924	14.956
.69	14.988	15.020	15.052	15.085	15.117	15.149	15.181	15.213	15.246	15.278
.70	15.310	15.342	15.375	15.407	15.440	15.472	15.505	15.537	15.570	15.602
.71	15.635	15.668	15.700	15.733	15.766	15.798	15.831	15.864	15.897	15.929
.72	15.962	15.995	16.028	16.061	16.094	16.126	16.159	16.192	16.225	16.258
.73	16.291	16.324	16.357	16.390	16.423	16.456	16.490	16.523	16.556	16.589
.74	16.622	16.655	16.689	16.722	16.756	16.789	16.822	16.856	16.889	16.923
.75	16.956	16.989	17.023	17.056	17.090	17.123	17.157	17.190	17.224	17.257
.76	17.291	17.325	17.358	17.392	17.426	17.459	17.493	17.527	17.561	17.594
.77	17.628	17.662	17.696	17.730	17.764	17.798	17.832	17.866	17.900	17.934
.78	17.968	18.002	18.036	18.070	18.104	18.138	18.173	18.207	18.241	18.275
.79	18.309	18.343	18.378	18.412	18.447	18.481	18.515	18.550	18.584	18.619
.80	18.653	18.687	18.722	18.756	18.791	18.825	18.860	18.894	18.929	18.963
.81	18.998	19.033	19.067	19.102	19.137	19.171	19.206	19.241	19.276	19.310
.82	19.345	19.380	19.415	19.450	19.485	19.520	19.555	19.590	19.625	19.660
.83	19.695	19.730	19.765	19.800	18.835	19.870	19.906	19.941	19.976	20.011
.84	20.046	20.081	20.117	20.152	20.187	20.223	20.258	20.293	20.329	20.364
.85	20.399	20.434	20.470	20.505	20.541	20.576	20.612	20.647	20.683	20.718
.86	20.754	20.790	20.825	20.861	20.897	20.932	20.968	21.004	21.040	21.075
.87	21.111	21.147	21.183	21.219	21.255	21.491	21.327	21.363	21.399	21.435
.88	21.471	21.507	21.543	21.579	21.615	21.651	21.688	21.724	21.760	21.796
.89	21.832	21.868	21.904	21.941	21.977	22.013	22.049	22.085	22.122	22.158
.90	22.194	22.230	22.267	22.303	22.340	22.376	22.412	22.449	22.485	22.522
.91	22.558	22.595	22.631	22.669	22.705	22.741	22.778	22.815	22.852	22.888
.92	22.925	22.962	22.999	23.035	23.072	23.109	23.146	23.183	23.219	23.256
.93	23.293	23.330	23.367	23.404	23.441	23.478	23.515	23.552	23.589	23.626
.94	23.663	23.700	23.737	23.774	23.811	23.848	23.886	23.923	23.960	23.997
.95	24.034	24.071	24.109	24.146	24.184	24.221	24.258	24.296	24.333	24.371
.96	24.408	24.445	24.483	24.520	24.558	24.595	24.633	24.670	24.708	24.745
.97	24.783	24.821	24.859	24.896	24.934	24.972	25.009	25.048	25.085	25.123
.98	25.161	25.199	25.237	25.274	25.312	25.350	25.388	25.426	25.463	25.501
.99	25.539	25.577	25.615	25.653	25.691	25.729	25.767	25.805	25.843	25.881
1.00	25.919	25.957	25.996	26.034	26.072	26.110	26.149	26.187	26.225	26.263
1.01	26.302	26.340	26.379	26.417	26.456	26.494	26.532	26.571	26.609	26.648
1.02	26.686	26.724	26.763	26.801	26.840	26.878	26.917	26.955	26.994	27.032
1.03	27.071	27.110	27.148	27.187	27.226	27.264	27.303	27.342	27.381	27.419
1.04	27.458	27.497	27.536	27.575	27.614	27.652	27.691	27.730	27.769	27.808
1.05	27.847	27.886	27.925	27.964	28.003	28.042	28.082	28.121	28.160	28.199
1.06	28.238	28.277	28.316	28.356	28.395	28.434	28.473	28.512	28.552	28.591
1.07	28.630	28.669	28.709	28.748	28.788	28.827	28.866	28.906	28.945	28.985
1.08	29.024	29.064	29.103	29.142	29.182	29.222	29.262	29.301	29.341	29.380
1.09	29.420	29.460	29.499	29.539	29.579	29.618	29.658	29.698	29.738	29.777
1.10	29.817	29.857	29.897	29.937	29.977	30.016	30.056	30.096	30.136	30.176
1.11	30.216	30.256	30.295	30.336	30.376	30.416	30.456	30.496	30.536	30.576
1.12	30.616	30.656	30.696	30.737	30.777	30.817	30.857	30.897	30.938	30.978
1.13	31.019	31.058	31.099	31.139	31.180	31.220	31.260	31.301	31.342	31.382
1.14	31.422	31.462	31.503	31.543	31.584	31.624	31.665	31.705	31.746	31.786
1.15	31.827	31.868	31.908	31.949	31.990	32.030	32.071	32.112	32.153	32.193
1.16	32.234	32.275	32.316	32.356	32.397	32.438	32.479	32.520	32.560	32.601
1.17	32.642	32.683	32.724	32.765	32.806	32.847	32.888	32.929	32.970	33.011
1.18	33.052	33.093	33.134	33.176	33.217	33.258	33.299	33.340	33.382	33.423
1.19	33.464	33.505	33.547	33.588	33.629	33.670	33.712	33.753	33.794	33.836
1.20	33.877	33.918	33.960	34.001	34.043	34.084	34.125	34.167	34.208	34.250
1.21	34.291	34.333	34.374	34.416	34.457	34.499	34.541	34.582	34.624	34.665
1.22	34.707	34.749	34.790	34.832	34.874	34.915	34.957	34.999	35.041	35.082
1.23	35.124	35.166	35.208	35.250	35.292	35.334	35.376	35.418	35.460	35.502
1.24	35.544	35.586	35.628	35.670	35.712	35.754	35.796	35.838	35.880	35.922
1.25	35.964	36.006	36.048	36.091	36.133	36.175	36.217	36.259	36.302	36.344
1.26	36.386	36.428	36.471	36.513	36.556	36.598	36.640	36.683	36.725	36.768
1.27	36.810	36.852	36.895	36.937	36.980	37.022	37.064	37.107	37.149	37.192
1.28	37.234	37.277	37.319	37.362	37.405	37.447	37.490	37.533	37.576	37.618
1.29	37.661	37.704	37.747	37.789	37.832	37.875	37.917	37.961	38.003	38.046
1.30	38.089	38.132	38.175	38.218	38.261	38.303	38.346	38.389	38.432	38.475
1.31	38.518	38.561	38.604	38.647	38.690	38.733	38.776	38.819	38.862	38.905
1.32	38.948	38.991	39.034	39.078	39.121	39.164	39.207	39.250	39.294	39.337
1.33	39.380	39.423	39.467	39.510	39.554	39.597	39.640	39.684	39.727	39.771
1.34	39.814	39.857	39.901	39.944	39.988	40.031	40.075	40.118	40.162	40.205
1.35	40.249	40.293	40.336	40.380	40.423	40.467	40.511	40.554	40.598	40.641
1.36	40.685	40.729	40.773	40.816	40.860	40.904	40.948	40.992	41.035	41.079
1.37	41.123	41.167	41.211	41.255	41.299	41.342	41.386	41.430	41.474	41.518
1.38	41.562	41.606	41.650	41.694	41.738	41.782	41.826	41.870	41.914	41.958
1.39	42.002	42.046	42.091	42.135	42.179	42.223	42.267	42.311	42.356	42.400
1.40	42.444	42.488	42.533	42.577	42.621	42.665	42.710	42.754	42.798	42.843
1.41	42.887	42.931	42.976	43.020	43.065	43.109	43.153	43.198	43.242	43.287
1.42	43.331	43.376	43.420	43.465	43.509	43.554	43.599	43.643	43.688	43.732
1.43	43.777	43.823	43.867	43.911	43.956	44.001	44.046	44.091	44.135	44.180
1.44	44.225	44.270	44.315	44.359	44.404	44.449	44.494	44.539	44.583	44.628
1.45	44.673	44.718	44.763	44.808	44.853	44.898	44.943	44.988	45.033	45.078
1.46	45.123	45.168	45.213	45.258	45.303	45.348	45.394	45.439	45.484	45.529
1.47	45.574	45.619	45.665	45.710	45.755	45.800	45.846	45.891	45.936	45.982
1.48	46.027	46.072	46.118	46.163	46.209	46.254	46.299	46.345	46.390	46.436
1.49	46.481	46.526	46.572	46.617	46.663	46.708	46.754	46.799	46.845	46.890
1.50	46.936	46.982	47.027	47.073	47.118	47.164	47.210	47.255	47.301	47.346
1.51	47.392	47.438	47.484	47.529	47.575	47.621	47.667	47.713	47.758	47.804
1.52	47.850	47.896	47.942	47.988	48.034	48.079	48.125	48.171	48.217	48.263
1.53	48.309	48.355	48.401	48.447	48.493	48.539	48.585	48.631	48.677	48.723
1.54	48.769	48.815	48.861	48.907	48.953	48.999	49.046	49.092	49.138	49.184
1.55	49.230	49.276	49.323	49.369	49.415	49.461	49.508	49.554	49.600	49.647
1.56	49.693	49.739	49.786	49.832	49.879	49.925	49.972	50.018	50.065	50.111
1.57	50.158	50.204	50.251	50.297	50.344	50.392	50.437	50.483	50.530	50.576
1.58	50.623	50.670	50.716	50.763	50.810	50.856	50.903	50.950	50.997	51.043
1.59	51.090	51.137	51.184	51.230	51.277	51.324	51.371	51.418	51.464	51.511
1.60	51.558	51.605	51.652	51.698	51.745	51.792	51.839	51.886	51.932	51.979
1.61	52.026	52.073	52.120	52.167	52.214	52.261	52.308	52.355	52.402	52.449
1.62	52.496	52.543	52.590	52.637	52.684	52.731	52.779	52.826	52.873	52.920
1.63	52.967	53.014	53.062	53.109	53.156	53.203	53.251	53.298	53.345	53.393
1.64	53.440	53.487	53.535	53.582	53.630	53.677	53.724	53.772	53.819	52.867
1.65	53.914	53.961	54.009	54.056	54.104	54.151	54.199	54.246	54.294	54.341
1.66	54.389	54.437	54.484	54.532	54.579

Head in ft.	0	1	2	3	4	5	6	7	8	9
1.90..	66.136	66.186	66.237	66.287	66.337	66.388	66.438	66.488	66.539	66.589
1.91..	66.639	66.689	66.740	66.790	66.841	66.891	66.941	66.992	67.042	67.093
1.92..	67.143	67.194	67.244	67.295	67.345	67.396	67.447	67.497	67.548	67.598
1.93..	67.649	67.700	67.750	67.801	67.852	67.902	67.953	68.003	68.055	68.105
1.94..	68.156	68.207	68.257	68.308	68.359	68.409	68.460	68.511	68.562	68.612
1.95..	68.663	68.714	68.765	68.815	68.866	68.917	68.968	69.019	69.069	69.120
1.96..	69.171	69.222	69.273	69.324	69.375	69.426	69.477	69.528	69.579	69.630
1.97..	69.681	69.732	69.783	69.834	69.885	69.936	69.988	70.039	70.090	70.141
1.98..	70.192	70.243	70.294	70.346	70.397	70.448	70.499	70.550	70.602	70.653
1.99..	70.704	70.755	70.806	70.858	70.909	70.960	71.011	71.062	71.114	71.165
2.00..	71.216	71.267	71.319	71.370	71.421	71.472	71.524	71.575	71.626	71.678

TABLE III.—(Continued.)

10-Ft. Weir.

Head in ft.	0	1	2	3	4	5	6	7	8	9
.00..	.034	.040	.046	.053	.059	.065	.071	.077	.084	.090
.01..	.096	.104	.112	.120	.128	.136	.145	.153	.161	.169
.02..	.177	.186	.196	.205	.215	.224	.234	.243	.253	.262
.03..	.272	.283	.294	.304	.315	.326	.337	.348	.358	.369
.04..	.380	.392	.404	.416	.428	.440	.452	.464	.476	.488
.05..	.500	.513	.526	.539	.552	.564	.577	.590	.603	.616
.06..	.629	.643	.657	.670	.684	.698	.712	.726	.739	.753
.07..	.767	.782	.797	.811	.826	.841	.857	.871	.885	.900
.08..	.915	.930	.946	.961	.977	.992	1.008	1.023	1.039	1.054
.09..	1.070	1.086	1.103	1.119	1.136	1.152	1.168	1.185	1.201	1.217
.10..	1.234	1.251	1.268	1.285	1.302	1.319	1.337	1.354	1.371	1.388
.11..	1.405	1.423	1.441	1.458	1.476	1.494	1.512	1.530	1.547	1.565
.12..	1.583	1.601	1.620	1.638	1.657	1.675	1.694	1.712	1.731	1.749
.13..	1.768	1.787	1.806	1.826	1.845	1.864	1.883	1.902	1.922	1.941
.14..	1.960	1.980	2.000	2.019	2.039	2.059	2.079	2.099	2.118	2.138
.15..	2.158	2.178	2.198	2.219	2.239	2.259	2.279	2.299	2.320	2.340
.16..	2.360	2.381	2.402	2.423	2.444	2.464	2.485	2.506	2.527	2.548
.17..	2.569	2.590	2.612	2.633	2.655	2.676	2.698	2.719	2.741	2.762
.18..	2.784	2.806	2.828	2.850	2.872	2.894	2.916	2.938	2.960	2.982
.19..	3.004	3.026	3.049	3.071	3.094	3.116	3.139	3.161	3.184	3.206
.20..	3.229	3.252	3.275	3.298	3.321	3.344	3.367	3.390	3.413	3.436
.21..	3.459	3.483	3.506	3.530	3.554	3.577	3.601	3.625	3.649	3.672
.22..	3.696	3.720	3.745	3.769	3.793	3.817	3.842	3.866	3.890	3.915
.23..	3.939	3.964	3.988	4.013	4.038	4.062	4.087	4.112	4.137	4.161
.24..	4.186	4.211	4.236	4.261	4.286	4.311	4.337	4.362	4.387	4.411
.25..	4.437	4.462	4.488	4.513	4.539	4.564	4.590	4.615	4.641	4.666
.26..	4.692	4.718	4.744	4.770	4.796	4.822	4.848	4.874	4.900	4.926
.27..	4.952	4.978	5.005	5.031	5.058	5.084	5.110	5.137	5.163	5.190
.28..	5.216	5.243	5.269	5.296	5.323	5.349	5.376	5.403	5.430	5.456
.29..	5.483	5.510	5.537	5.564	5.591	5.618	5.645	5.672	5.699	5.726
.30..	5.753	5.780	5.808	5.835	5.863	5.890	5.917	5.945	5.972	6.000
.31..	6.027	6.055	6.083	6.110	6.138	6.166	6.194	6.222	6.249	6.277
.32..	6.305	6.333	6.361	6.389	6.417	6.445	6.474	6.502	6.530	6.558
.33..	6.586	6.615	6.643	6.672	6.700	6.729	6.758	6.786	6.815	6.843
.34..	6.872	6.901	6.930	6.959	6.988	7.017	7.047	7.076	7.105	7.134
.35..	7.163	7.192	7.222	7.251	7.281	7.310	7.339	7.369	7.398	7.428
.36..	7.457	7.487	7.517	7.546	7.576	7.606	7.636	7.666	7.695	7.725
.37..	7.755	7.785	7.815	7.846	7.876	7.906	7.936	7.966	7.996	8.027
.38..	8.057	8.087	8.118	8.148	8.179	8.209	8.240	8.270	8.301	8.331
.39..	8.362	8.393	8.424	8.455	8.486	8.516	8.547	8.578	8.609	8.640
.40..	8.671	8.702	8.734	8.765	8.797	8.828	8.859	8.891	8.922	8.953
.41..	8.985	9.017	9.049	9.081	9.113	9.145	9.177	9.209	9.241	9.273
.42..	9.305	9.337	9.370	9.402	9.435	9.467	9.499	9.532	9.564	9.597
.43..	9.630	9.662	9.695	9.728	9.761	9.794	9.828	9.861	9.894	9.927
.44..	9.960	9.993	10.026	10.060	10.093	10.126	10.159	10.192	10.226	10.259
.45..	10.293	10.326	10.359	10.392	10.426	10.459	10.493	10.526	10.560	10.593
.46..	10.627	10.661	10.694	10.728	10.762	10.795	10.829	10.863	10.897	10.930
.47..	10.964	10.998	11.032	11.066	11.100	11.133	11.167	11.201	11.235	11.269
.48..	11.303	11.337	11.371	11.406	11.440	11.474	11.508	11.542	11.577	11.611
.49..	11.645	11.680	11.714	11.749	11.783	11.818	11.853	11.887	11.922	11.956
.50..	11.991	12.026	12.061	12.096	12.131	12.166	12.201	12.236	12.271	12.306
.51..	12.341	12.376	12.412	12.447	12.482	12.517	12.553	12.588	12.623	12.659
.52..	12.694	12.730	12.766	12.801	12.837	12.873	12.909	12.945	12.980	13.016
.53..	13.052	13.088	13.125	13.161	13.197	13.233	13.270	13.306	13.342	13.379
.54..	13.415	13.452	13.488	13.525	13.562	13.598	13.635	13.672	13.709	13.745
.55..	13.782	13.819	13.856	13.893	13.930	13.967	14.004	14.041	14.078	14.115
.56..	14.152	14.189	14.227	14.264	14.302	14.339	14.376	14.414	14.451	14.489
.57..	14.526	14.564	14.602	14.639	14.677	14.715	14.753	14.791	14.828	14.866
.58..	14.904	14.942	14.980	15.018	15.056	15.094	15.133	15.171	15.209	15.247
.59..	15.285	15.323	15.362	15.400	15.439	15.477	15.515	15.554	15.592	15.631
.60..	15.669	15.708	15.746	15.785	15.824	15.862	15.901	15.940	15.979	16.017
.61..	16.056	16.095	16.134	16.173	16.212	16.251	16.290	16.329	16.368	16.407
.62..	16.446	16.485	16.524	16.564	16.603	16.642	16.681	16.720	16.760	16.799
.63..	16.838	16.877	16.917	16.956	16.996	17.035	17.074	17.114	17.153	17.193
.64..	17.232	17.272	17.311	17.351	17.390	17.430	17.470	17.509	17.549	17.588
.65..	17.628	17.668	17.707	17.747	17.787	17.826	17.866	17.906	17.946	17.985
.66..	18.025	18.065	18.105	18.144	18.184	18.224	18.264	18.304	18.343	18.383
.67..	18.423	18.463	18.503	18.543	18.583	18.623	18.663	18.703	18.743	18.783
.68..	18.823	18.863	18.904	18.944	18.984	19.024	19.065	19.105	19.145	19.186
.69..	19.226	19.266	19.307	19.347	19.388	19.428	19.469	19.509	19.550	19.590
.70..	19.631	19.672	19.713	19.753	19.794	19.835	19.876	19.917	19.957	19.998
.71..	20.039	20.080	20.121	20.162	20.203	20.244	20.285	20.326	20.367	20.408
.72..	20.449	20.490	20.532	20.573	20.614	20.656	20.697	20.738	20.779	20.820
.73..	20.862	20.904	20.945	20.987	21.028	21.070	21.112	21.153	21.195	21.236
.74..	21.278	21.320	21.362	21.404	21.446	21.488	21.530	21.572	21.614	21.656
.75..	21.698	21.740	21.783	21.825	21.868	21.910	21.952	21.995	22.037	22.080
.76..	22.122	22.165	22.207	22.250	22.293	22.335	22.378	22.421	22.464	22.506
.77..	22.549	22.592	22.635	22.678	22.721	22.764	22.807	22.850	22.893	22.936
.78..	22.979	23.022	23.066	23.109	23.152	23.195	23.239	23.282	23.325	23.369
.79..	23.412	23.455	23.499	23.542	23.586	23.629	23.672	23.715	23.759	23.803
.80..	23.846	23.890	23.933	23.977	24.021	24.064	24.108	24.152	24.196	24.239
.81..	24.283	24.327	24.371	24.415	24.459	24.503	24.547	24.591	24.635	24.679
.82..	24.723	24.767	24.811	24.856	24.900	24.944	24.988	25.032	25.077	25.121
.83..	25.165	25.209	25.254	25.298	25.343	25.387	25.432	25.476	25.521	25.565
.84..	25.610	25.655	25.699	25.744	25.789	25.833	25.878	25.923	25.967	26.012
.85..	26.057	26.102	26.147	26.192	26.237	26.282	26.327	26.372	26.417	26.462
.86..	26.507	26.552	26.598	26.643	26.688	26.733	26.779	26.824	26.869	26.915
.87..	26.960	27.005	27.051	27.096	27.142	27.187	27.233	27.278	27.324	27.369
.88..	27.415	27.461	27.507	27.552	27.598	27.644	27.689	27.736	27.781	27.827
.89..	27.873	27.919	27.965	28.011	28.057	28.103	28.149	28.195	28.241	28.287
.90..	28.333	28.379	28.425	28.471	28.517	28.563	28.610	28.656	28.702	28.748
.91..	28.794	28.840	28.887	28.933	28.980	29.026	29.072	29.119	29.165	29.212
.92..	29.258	29.305	29.351	29.398	29.445	29.491	29.538	29.585	29.632	29.678
.93..	29.725	29.772	29.819	29.865	29.912	29.959	30.006	30.053	30.099	30.146
.94..	30.193	30.240	30.287	30.334	30.381	30.428	30.475	30.522	30.569	30.616
.95..	30.663	30.710	30.757	30.805	30.852	30.899	30.946	30.993	31.041	31.088
.96..	31.135	31.182	31.230	31.277	31.325	31.372	31.419	31.467	31.514	31.562
.97..	31.609	31.657	31.704	31.752	31.799	31.847	31.895	31.942	31.990	32.037
.98..	32.085	32.133	32.181	32.228	32.276	32.324	32.372	32.420	32.467	32.515
.99..	32.563	32.611	32.659	32.707	32.755	32.803	32.851	32.899	32.947	32.995
1.00..	33.043	33.091	33.140	33.188	33.236	33.284	33.333	33.381	33.429	33.478
1.01..	33.526	33.575	33.623	33.671	33.720	33.758	33.818	33.866	33.916	33.963
1.02..	34.012	34.061	34.110	34.159	34.208	34.256	34.305	34.354	34.403	34.452
1.03..	34.501	34.550	34.600	34.649	34.699	34.748	34.797	34.847	34.896	34.945
1.04..	34.995	35.044	35.094	35.143	35.193	35.242	35.292	35.341	35.391	35.440
1.05..	35.490	35.539	35.589	35.638	35.688	35.737	35.787	35.836	35.886	35.935
1.06..	35.985	36.035	36.084	36.134	36.184	36.233	36.283	36.333	36.383	36.432
1.07..	36.482	36.532	36.582	36.632	36.682	36.731	36.781	36.831	36.881	36.931
1.08..	36.981	37.031	37.081	37.132	37.182	37.232	37.282	37.332	37.382	37.432
1.09..	37.483	37.533	37.584	37.633	37.684	37.734	37.784	37.835	37.885	37.936
1.10..	37.986	38.036	38.087	38.137	38.188	38.238	38.289	38.339	38.390	38.440
1.11..	38.491	38.542	38.592	38.643	38.694	38.744	38.796	38.847	38.898	38.948
1.12..	38.998	39.049	39.100	39.151	39.202	39.253	39.304	39.355	39.406	39.457
1.13..	39.508	39.559	39.610	39.661	39.712	39.763	39.815	39.866	39.917	39.968
1.14..	40.019	40.070	40.122	40.173	40.225	40.276	40.327	40.379	40.430	40.482
1.15..	40.533	40.585	40.636	40.688	40.739	40.791	40.843	40.894	40.946	40.997
1.16..	41.049	41.101	41.153	41.204	41.256	41.308	41.360	41.412	41.463	41.515

Head in ft.	0	1	2	3	4	5	6	7	8	9
1.18..	41.567	41.619	41.671	41.723	41.775	41.827	41.879	41.931	41.983	42.035
1.19..	42.087	42.139	42.191	42.243	42.295	42.347	42.400	42.452	42.504	42.556
1.20..	42.608	42.660	42.713	42.765	42.818	42.870	42.922	42.975	43.027	43.080
1.21..	43.132	43.184	43.237	43.289	43.342	43.394	43.447	43.499	43.552	43.604
1.22..	43.657	43.710	43.762	43.815	43.868	43.920	43.973	44.026	44.079	44.131
1.23..	44.184	44.237	44.290	44.343	44.396	44.448	44.501	44.554	44.607	44.660
1.24..	44.713	44.766	44.819	44.872	44.925	44.978	45.032	45.085	45.138	45.191
1.25..	45.244	45.297	45.351	45.404	45.458	45.511	45.564	45.618	45.671	45.725
1.26..	45.778	45.832	45.885	45.939	45.992	46.046	46.100	46.153	46.207	46.260
1.27..	46.314	46.368	46.421	46.475	46.529	46.582	46.636	46.690	46.744	46.797
1.28..	46.851	46.905	46.959	47.013	47.067	47.120	47.174	47.228	47.282	47.336
1.29..	47.390	47.444	47.498	47.552	47.607	47.661	47.715	47.769	47.824	47.878
1.30..	47.932	47.986	48.041	48.095	48.149	48.203	48.258	48.312	48.366	48.421
1.31..	48.475	48.529	48.584	48.638	48.693	48.747	48.802	48.856	48.911	48.965
1.32..	49.020	49.075	49.129	49.184	49.238	49.293	49.348	49.402	49.457	49.511
1.33..	49.566	49.621	49.675	49.730	49.785	49.839	49.894	49.949	50.004	50.058
1.34..	50.113	50.168	50.223	50.278	50.333	50.387	50.442	50.497	50.552	50.607
1.35..	50.662	50.717	50.772	50.828	50.883	50.938	50.993	51.048	51.104	51.159
1.36..	51.214	51.269	51.325	51.380	51.436	51.491	51.546	51.602	51.657	51.713
1.37..	51.768	51.824	51.879	51.935	51.990	52.046	52.102	52.157	52.213	52.268
1.38..	52.324	52.380	52.435	52.491	52.547	52.602	52.658	52.714	52.770	52.825
1.39..	52.881	52.937	52.993	53.049	53.105	53.160	53.216	53.272	53.328	53.384
1.40..	53.440	53.496	53.552	53.608	53.664	53.720	53.776	53.832	53.888	53.944
1.41..	54.000	54.056	54.117	54.169	54.225	54.281	54.338	54.394	54.450	54.507
1.42..	54.563	54.619	54.676	54.732	54.789	54.845	54.902	54.958	55.015	55.071
1.43..	55.128	55.185	55.241	55.298	55.354	55.411	55.468	55.524	55.581	55.637
1.44..	55.694	55.751	55.808	55.864	55.921	55.978	56.035	56.092	56.148	56.205
1.45..	56.262	56.319	56.376	56.433	56.490	56.546	56.603	56.660	56.717	56.774
1.46..	56.831	56.888	56.945	57.003	57.060	57.117	57.174	57.231	57.289	57.346
1.47..	57.403	57.460	57.518	57.575	57.632	57.689	57.747	57.804	57.861	57.919
1.48..	57.976	58.033	58.091	58.148	58.206	58.263	58.320	58.378	58.435	58.493
1.49..	58.550	58.608	58.665	58.723	58.781	58.838	58.896	58.954	59.012	59.069
1.50..	59.127	59.185	59.243	59.300	59.358	59.416	59.474	59.532	59.589	59.647
1.51..	59.705	59.763	59.821	59.879	59.937	59.995	60.053	60.111	60.169	60.227
1.52..	60.285	60.343	60.401	60.459	60.517	60.575	60.634	60.692	60.750	60.808
1.53..	60.866	60.924	60.983	61.041	61.099	61.157	61.216	61.274	61.332	61.391
1.54..	61.449	61.507	61.566	61.624	61.683	61.741	61.800	61.858	61.917	61.975
1.55..	62.034	62.093	62.151	62.210	62.269	62.327	62.386	62.445	62.504	62.562
1.56..	62.621	62.680	62.739	62.798	62.857	62.915	62.974	63.033	63.092	63.151
1.57..	63.210	63.269	63.328	63.387	63.446	63.505	63.564	63.623	63.682	63.741
1.58..	63.800	63.859	63.918	63.978	64.037	64.096	64.155	64.214	64.274	64.333
1.59..	64.392	64.451	64.511	64.570	64.629	64.688	64.748	64.807	64.866	64.926
1.60..	64.985	65.044	65.104	65.163	65.223	65.282	65.341	65.401	65.460	65.520
1.61..	65.579	65.639	65.698	65.758	65.817	65.877	65.937	65.996	66.056	66.115
1.62..	66.175	66.235	66.294	66.354	66.414	66.473	66.533	66.593	66.653	66.712
1.63..	66.772	66.832	66.892	66.952	67.012	67.071	67.131	67.191	67.251	67.311
1.64..	67.371	67.431	67.491	67.551	67.611	67.671	67.731	67.791	67.851	67.911
1.65..	67.971	68.031	68.091	68.152	68.212	68.272	68.332	68.392	68.453	68.513
1.66..	68.573	68.633	68.694	68.754	68.815	68.875	68.936	68.996	69.057	69.117
1.67..	69.178	69.239	69.299	69.360	69.421	69.481	69.542	69.603	69.664	69.724
1.68..	69.785	69.846	69.907	69.967	70.028	70.089	70.150	70.211	70.271	70.332
1.69..	70.393	70.454	70.515	70.578	70.637	70.697	70.758	70.819	70.880	70.941
1.70..	71.002	71.063	71.124	71.185	71.246	71.307	71.369	71.430	71.491	71.552
1.71..	71.613	71.674	71.735	71.797	71.858	71.919	71.980	72.041	72.103	72.164
1.72..	72.225	72.286	72.348	72.409	72.470	72.531	72.593	72.654	72.715	72.777
1.73..	72.838	72.899	72.961	73.022	73.084	73.145	73.207	73.268	73.330	73.391
1.74..	73.453	73.515	73.576	73.638	73.699	73.761	73.823	73.884	73.946	74.007
1.75..	74.069	74.131	74.193	74.254	74.316	74.378	74.440	74.502	74.563	74.625
1.76..	74.687	74.749	74.811	74.873	74.935	74.996	75.058	75.120	75.182	75.244
1.77..	75.306	75.368	75.430	75.492	75.554	75.616	75.679	75.741	75.803	75.865
1.78..	75.927	75.989	76.052	76.114	76.176	76.238	76.301	76.363	76.425	76.487
1.79..	76.550	76.612	76.675	76.737	76.800	76.862	76.924	76.987	77.049	77.112
1.80..	77.174	77.236	77.299	77.361	77.424	77.486	77.549	77.611	77.674	77.736
1.81..	77.799	77.862	77.924	77.987	78.050	78.112	78.175	78.238	78.301	78.363
1.82..	78.426	78.489	78.552	78.615	78.678	78.740	78.803	78.866	78.929	78.992
1.83..	79.055	79.118	79.181	79.244	79.307	79.370	79.433	79.496	79.559	79.622
1.84..	79.685	79.748	79.811	79.874	79.937	80.000	80.064	80.127	80.190	80.253
1.85..	80.316	80.379	80.443	80.506	80.569	80.633	80.696	80.759	80.822	80.886
1.86..	80.949	81.012	81.076	81.139	81.203	81.266	81.329	81.393	81.456	81.520
1.87..	81.583	81.647	81.710	81.774	81.837	81.901	81.965	82.028	82.092	82.155
1.88..	82.219	82.283	82.346	82.410	82.474	82.537	82.601	82.665	82.729	82.792
1.89..	82.856	82.920	82.984	83.047	83.111	83.175	83.239	83.303	83.366	83.430
1.90..	83.494	83.558	83.622	83.686	83.750	83.814	83.878	83.942	84.006	84.070
1.91..	84.134	84.198	84.262	84.326	84.390	84.454	84.519	84.583	84.647	84.711
1.92..	84.775	84.839	84.904	84.968	85.032	85.096	85.161	85.225	85.289	85.354
1.93..	85.418	85.482	85.547	85.611	85.676	85.740	85.805	85.869	85.934	85.998
1.94..	86.063	86.128	86.192	86.257	86.321	86.386	86.451	86.515	86.580	86.644
1.95..	86.709	86.774	86.838	86.903	86.968	87.032	87.097	87.162	87.227	87.291
1.96..	87.356	87.421	87.486	87.550	87.615	87.680	87.745	87.810	87.874	87.939
1.97..	88.004	88.069	88.134	88.199	88.264	88.329	88.394	88.459	88.524	88.589
1.98..	88.654	88.719	88.784	88.849	88.914	88.979	89.045	89.109	89.175	89.240
1.99..	89.305	89.370	89.435	89.501	89.566	89.631	89.696	89.761	89.827	89.892
2.00..	89.957	90.022	90.088	90.153	90.219	90.284	90.349	90.415	90.480	90.545
2.01..	90.611	90.676	90.742	90.807	90.873	90.938	91.004	91.069	91.135	91.200
2.02..	91.266	91.332	91.397	91.463	91.528	91.594	91.660	91.725	91.791	91.856
2.03..	91.922	91.988	92.054	92.119	92.185	92.251	92.317	92.383	92.448	92.514
2.04..	92.580	92.646	92.712	92.778	92.844	92.910	92.976	93.042	93.108	93.174
2.05..	93.240	93.306	93.372	93.438	93.504	93.570	93.637	93.703	93.769	93.835
2.06..	93.901	93.967	94.033	94.100	94.166	94.232	94.298	94.364	94.431	94.496
2.07..	94.563	94.629	94.696	94.762	94.828	94.894	94.961	95.027	95.093	95.160
2.08..	95.226	95.292	95.359	95.425	95.492	95.558	95.625	95.691	95.758	95.824
2.09..	95.891	95.958	96.024	96.091	96.157	96.224	96.291	96.357	96.424	96.490
2.10..	96.557	96.624	96.690	96.757	96.824	96.890	96.957	97.024	97.091	97.157
2.11..	97.224	97.291	97.358	97.425	97.492	97.558	97.625	97.692	97.759	97.826
2.12..	97.893	97.960	98.027	98.094	98.161	98.228	98.295	98.362	98.429	98.496
2.13..	98.563	98.630	98.697	98.764	98.831	98.898	98.966	99.033	99.100	99.167
2.14..	99.234	99.301	99.368	99.436	99.503	99.570	99.637	99.704	99.772	99.839
2.15..	99.906	99.973	100.041	100.108	100.175	100.242	100.310	100.377	100.444	100.512
2.16..	100.579	100.646	100.714	100.781	100.849	100.916	100.984	101.051	101.119	101.186
2.17..	101.254	101.322	101.389	101.457	101.525	101.592	101.660	101.728	101.796	101.863
2.18..	101.931	101.999	102.067	102.134	102.202	102.270	102.338	102.406	102.473	102.541
2.19..	102.609	102.677	102.745	102.813	102.881	102.948	103.016	103.084	103.152	103.220
2.20..	103.288	103.356	103.424	103.492	103.560	103.628	103.696	103.764	103.832	103.900
2.21..	103.968	104.036	104.104	104.172	104.240	104.308	104.377	104.445	104.513	104.581
2.22..	104.649	104.717	104.786	104.854	104.922	104.990	105.059	105.127	105.195	105.264